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Notes on Limitations of Natural Control of Phytophagous Insects and Mites in a British Columbia Orchard[1]

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When an apple orchard is abandoned in Eastern Canada the trees may continue to grow reasonably well for many years. As a rule the fruit is ruined by apple scab, but damage from insects or mites may be relatively minor. Under such conditions, phytophagous insects and mites are commonly held to an acceptable commercial level by natural control factors. On the other hand, when an apple orchard is abandoned in the semi-arid, southern interior of British Columbia the trees generally die from desiccation in a short time. Occasionally, when particularly favoured by sub-irrigation, they may survive for ten years or more. But they produce no marketable fruit; invariably it is ruined by insects. Unlike the abandoned eastern orchard, that in British Columbia has little natural protection from the codling moth, *Carpocapsa pomonella* (L.), and the blister mite, *Eriophyes pyri* (Pgst.), to mention but two common pests.

To the fruit grower the natural control of insects in the abandoned orchard may be an academic matter; not so natural control in the commercial orchard. Reports about organic farming and its insistence on the natural control of orchard pests and about the modified spray program in Nova Scotia (Pickett and Patterson, 1953) have raised some questions in British Columbia as to the wisdom of using chemicals, whether fertilizers or pesticides. This paper gives results of an experiment on the outcome of no-pesticide culture in an orchard that otherwise received good care.

When the Entomology Laboratory was established at Summerland in the Okanagan Valley of British Columbia in 1946, a three-acre experimental orchard was planted nearby. The orchard consists of commercial varieties of apricot, sweet cherry, peach, pear, plum, prune, and apple. It is approximately 250 yards from the nearest commercial plantings.

Before the trees were set out, the orchard area had been grassland. For a year after planting it was clean-cultivated; then it was seeded to alfalfa, ladino clover, white Dutch clover, Kentucky blue grass, fescue, and brome grass, each in a half-acre plot. Since then the cover-crops have been flattened as necessary with a steel cover-crop roller, or mowed with a rotary brush and grass cutter. The orchard is sprinkler-irrigated. It has received applications of boron at three-year intervals and ammonium phosphate or ammonium nitrate annually. In these respects, the orchard has been well cared for. In another respect it differs from all other well-tended orchards in British Columbia: it has received no chemical treatments for the control of insects or mites. The peach trees alone have been sprayed at the dormant stage with bordeaux mixture for the control of peach leaf curl.

Since 1951, when the orchard began to yield, annual observations have been made to record the arrival of insects and mites of economic importance, and the severity of their attacks. From time to time attempts have been made to colonize soft scales and certain other insects in the orchard, but with little

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success. Consequently, the species which have become economically injurious have arrived in the orchard by natural dispersal. In Table 1, the observations are summarized.

TABLE I

Incidence of phytophagous insects and mites and damage caused to crops in insecticide-free orchard, Summerland, 1946–1954

Species	Degree of infestation	Estimated economic damage	
		Persistent or sporadic	Range, %*
1. *Apricot*			
Mealy plum aphid, *Hyalopterus arundinis* (F.)	Light to severe	Persistent since 1952	1 to 20
Thistle aphid, *Anuraphis cardui* (L.)	Light	Sporadic	0
Green peach aphid, *Myzus persicae* (Sulz.)	Light	Sporadic	0
Peach twig borer, *Anarsia lineatella* Zell.	Light	Sporadic	0
2. *Peach*			
Green peach aphid, *Myzus persicae* (Sulz.)	Nil to moderate	Sporadic	0
Peach twig borer, *Anarsia lineatella* Zell.	Light	Sporadic	0 to 10
Lygus bugs, *Lygus* sp.	Light to moderate	Sporadic	0 to 20
European red mite, *Metatetranychus ulmi* (Koch)	Very light to light	Sporadic	0
Two-spotted spider mite, *Tetranychus bimaculatus* Harvey	Very light to moderate	Sporadic	0
Eriophyid (rust) mites	Very light to moderate	Sporadic	0
3. *Plum and Prune*			
Mealy plum aphid, *Hyalopterus arundinis* (F.)	Moderate to heavy	Persistent	15 to 40
Thistle aphid, *Anuraphis cardui* (L.)	Light to moderate	Sporadic	0
European red mite, *Metatetranychus ulmi* (Koch)	Light to heavy	Sporadic	0 to 5
Eriophyid (rust) mites	Light to moderate	Persistent	0 to 2
4. *Cherry*			
Black cherry aphid, *Myzus cerasi* (F.)	Very heavy	Persistent	100
Fruit tree leaf roller, *Archips argyrospila* (Wlkr.)	Light	Sporadic	0 to 1
Eye-spotted bud moth, *Spilonota ocellana* (D. & S.)	Light	Persistent	0 to 2
Codling moth, *Carpocapsa pomonella* (L.)	Very light	Sporadic	0
Eriophyid (rust) mites	Light to heavy	Sporadic to 1953	5 (one year)
Clover mite, *Bryobia praetiosa* Koch	Light	Persistent	0
European red mite, *Metatetranychus ulmi* (Koch)	Light	Persistent	0
5. *Pear*			
Pear psylla, *Psylla pyricola* Förster	Light to moderate	Persistent	0 to 5
Pear-slug, *Caliroa cerasi* (L.)	Light	Sporadic	0
Codling moth, *Carpocapsa pomonella* (L.)	Light to moderate	Persistent	1 to 25
Eriophyid (blister) mite, *Eriophyes pyri* (Pgst.)	Light to moderate	Persistent	0 to 2
Eriophyid (rust) mites	Light	Persistent	0 to 3
European red mite, *Metatetranychus ulmi* (Koch)	Very light	Persistent	0
Clover mite, *Bryobia praetiosa* Koch	Very light	Persistent	0

*Estimated damage either to the current year's crop (blemished, poorly coloured, or undersized fruit, or premature abscission of fruit) or to the following year's crop (decreased yield resulting from impoverished foliage). Since several types of insects or mites may have damaged the same fruits the percentages of injury cannot be combined to give an estimate of total loss.

Species	Degree of infestation	Estimated economic damage	
		persistent or sporadic	Range, %*
	6. *Apple*		
White apple leafhopper, *Typhlocyba pomaria* McA.	Heavy	Persistent	15
Rosy apple aphid, *Anuraphis roseus* Baker.	Nil to moderate	Sporadic	5 (1953)
Apple aphid, *Aphis pomi* Deg.	Moderate to heavy	Persistent	2 to 10
Woolly apple aphid, *Eriosoma lanigerum* (Hausm.)	Light to heavy	Persistent	0 to 10
Eye-spotted bud moth, *Spilonota ocellana* (D. & S.)	Light to heavy	Persistent	1 to 10
Cigar casebearer, *Coleophora occidentalis* Zell.	Very light	Sporadic	0
Fruit tree leaf roller, *Archips argyrospila* (Wlkr.)	Light	Persistent	1 to 5
Codling moth, *Carpocapsa pomonella* (L.)	Moderate to heavy	Persistent (appeared when trees began to yield)	85 (average 1952–1955)
Plant bugs, *Lygus* spp.	Light	Persistent	0
Thrips, *Frankliniella* sp.	Moderate (on McIntosh, 1954)	Sporadic	0 to 1
Eriophyid (blister) mite, *Eriophyes pyri* (Pgst.)	Moderate (on Newton only)	Persistent	2 (on Newton only)
Eriophyid (rust mites)	Light to heavy	Persistent	0 to 5
European red mite, *Metatetranychus ulmi* (Koch)	Very light to heavy	Persistent	0 to 5
Clover mite, *Bryobia praetiosa* Koch	Light	Persistent	0
Two-spotted spider mite, *Tetranychus bimaculatus* Harvey	Light	Sporadic	0

Downing, Morgan, and Proverbs (1955) list a large number of insects and mites attacking fruit trees in the interior of British Columbia. Table 2, of which the first two columns were prepared from their compilation, shows that about half of the economically injurious species have not yet been found in the orchard of the Entomology Laboratory at Summerland.

As in the case of the phytophagous insects and mites, presumably the predatory and predacious species normally present in long-established orchards are not yet fully represented in the experimental orchard. Be that as it may, here is what has occurred, entomologically speaking, in this well-tended but non-sprayed orchard:—

1. Even in seasons decidedly unfavourable for the development of the codling moth, that insect has virtually destroyed the apple crop. The white apple leafhopper has invariably caused a great deal of damage to apple foliage. Doubtless the foliage injury resulted in a considerable decrease in the productivity of the trees, but the crop loss was not determined.

2. The pear crop has suffered up to 35 per cent loss, largely from the codling moth, the pear psylla, and eriophyid mites.

3. In some seasons the mealy plum aphid has caused about 25 per cent loss to the crop of Tilton apricot. Crops of Blenheim and Wenatchee Moorpark have been less seriously affected.

4. Loss of plums from aphids has averaged between 25 and 35 per cent.

5. The black cherry aphid has caused complete loss of the cherry crop year after year.

TABLE II

Numbers of species of insects and mites attacking various fruit trees in British Columbia (Downing *et al.*, in press) and numbers of species of economic importance established in the province and in insecticide-free orchard ten years after planting

Host	Species reported in B.C.	Economic species	
		In province	In insecticide-free orchard
Apple	47	25	15
Pear	21	12	7
Peach	23	13	6
Apricot	20	11	4
Plum and prune	28	12	4
Cherry	34	14	7

6. The peach orchard has averaged less than 10 per cent crop loss and at no time has been seriously affected either by insects or by mites.

The ruinous effects of codling moth infestation were expected, as were the losses inflicted by the black cherry aphid. But the persistent and distinctly injurious attacks of the apple aphid, the mealy plum aphid, and the white apple leafhopper were surprising. On the other hand, losses from the species of orchard mites that are most troublesome in commercial plantings (European red mite, clover mite, two-spotted spider mite, yellow spider mite, Pacific mite, and pear leaf blister mite) have been negligible. Nevertheless, occasionally the European red mite has been fairly numerous on apple, plum, and prune foliage. Those taxonomically little-known orchard pests, the free-living eriophyid (rust) mites, have from time to time been fairly injurious to the foliage of pear, cherry, apple, peach, plum, and prune. The frequency of their occurrence, so far, has paralleled that in commercial plantings.

This experiment on the natural control of insects and mites attacking orchards offers little hope that apples, pears, cherries, or plums could be raised profitably in the interior of British Columbia without the use of insecticides. It is true that the peach and apricot plantings, have required no insecticidal treatment during the ten years since they were set out in the experimental orchard; but there is ample evidence from commercial operations that insects such as the peach tree borer, *Sanninoidea exitiosa exitiosa* (Say), the peach twig borer, *Anarsia lineatella* Zell., and, in the South Okanagan and Similkameen valleys, the San Jose scale, *Aspidiotus perniciosus* Comst., are capable of causing serious and continuing losses whether or not insecticides have been used previously.

From the entomological point of view, as indicated earlier, conditions in the orchards of the interior of British Columbia are in sharp contrast with those in the other orchard areas of Canada, for example, the Annapolis Valley of Nova Scotia. There the chief limiting factor in apple production is neither insect nor mite attack but apple scab infection; if apple scab is controlled with fungicides that do not promote the development of phytophagous insects or mites, no more than an application or two of nicotine or ryania may be necessary.

Until 1948, apple powdery mildew was the most persistent and troublesome disease of the main fruit growing areas of the British Columbia interior. From

1948 to 1954, unusually cool or humid summers were the rule and apple scab became increasingly prevalent. At the present time the use of fungicides may be quite as important to most apple growers as the use of insecticides. Whether the high incidence of apple scab, like the insect attacks, will continue or will subside with the return of the hot, dry summers that usually prevail in central British Columbia, no one yet knows. In the meantime, the British Columbia apple grower is faced with the necessity of preventive spraying for apple scab, apple powdery mildew, and the codling moth. Fortunately, lime-sulphur, which is widely used in this area, helps to control both scab and mildew.

Experiments have shown that ryania as recommended for control of the codling moth in Nova Scotia (Patterson and Pickett, 1955) is inadequate in British Columbia. Hence, to control his arch enemy the codling moth, the British Columbia fruit grower, whether he likes the idea or not, must spray with DDT or methoxychlor, both of which are capable of upsetting the "biological balance" in his orchard. He must accept the fact that the use of either of these chlorinated hydrocarbons may in turn force the use of acaricides or aphicides.

The situation in British Columbia, however, is not at all discouraging. The general adoption of concentrate spraying has greatly reduced both the cost of spray application and its unpleasantness. Knowledge of interrelations of the orchard fauna is steadily increasing, as well as knowledge of the effects of spray chemicals on those interrelations.

Long-term ecological studies under way at Summerland are gradually putting the control of orchard insects and mites in British Columbia on a sound basis. Advisers are becoming more confident as to when it is wise to spray and when, despite the presence of injurious species of insects or mites, it is wise to refrain from spraying. Furthermore, these studies are giving increasing guidance in the choice not only of insecticides and acaricides but also of fungicides. Corrective spraying is emphasized whenever possible in preference to preventive spraying, and selective toxicants in preference to indiscriminately lethal or "shotgun" toxicants. The casual days of insect control seem to be finished. Applied entomology in the orchard has become a purposeful search for the most economical means of controlling insects and mites, natural if possible, chemical if necessary.

Summary

An experimental orchard at Summerland, British Columbia, received no insecticidal treatments since it was planted in 1946 and, except on peach trees, no fungicidal treatments. Insect injury has been so extensive that few sound fruits have been harvested from apple, sweet cherry, and prune trees. Pears have been somewhat less heavily attacked, apricots still less so, and peaches least of all. Comparison of these results with insect damage in the orchards of Eastern Canada suggests that the British Columbia fruit grower is more dependent on chemical control measures than his eastern contemporaries.

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Some Larvae of the Genus *Itame* Hübner (Lepidoptera: Geometridae)[1]

By W. C. McGuffin[2]

Introduction

Although many forest insects feed in or on trees, a larger number live on the shrubs and herbs of the forest floor. The shrub and herb feeders should not be overlooked since they comprise an important part of the fauna and may serve as reservoir hosts of parasites of the more destructive forest insects. Some larvae of the genus *Itame* are tree feeders but many of them feed on shrubs. These larvae are frequently collected within the Boreal Zone of Canada. As no means for the identification of the larvae could be found in the literature this paper was written. It consists of an account of the life history and external morphology of the larvae of the genus, a key to separate the mature larvae and descriptions of ten species. These species are: *I. ribearia* (Fitch), *I. evagaria* (Hlst.), *I. brunneata* (Thunb.), *I. andersoni* Swett, *I. occiduaria* (Pack.), *I. anataria* (Swett), *I. exauspicata* (Wlk.), *I. bitactata* (Wlk.), *I. denticulodes* (Hlst.), and *I. decorata* (Hlst.). Studies of the first four species are based on material obtained on loans and studies of the other species were made on material reared by the Forest Insect Survey of the Forest Zoology Laboratory, Calgary, Alberta.

Life History

Although several species of *Itame* are of economic importance where gooseberries, currants, and blueberries are grown commercially, there is little information on this life history. One of the most complete accounts is that of Franklin (1948). He records that each female moth of the green cranberry spanworm, *I. sulphurea* (Pack.), scatters about 125 eggs singly among the litter under the cranberry plants. The eggs overwinter and then hatch in late May or June. The larvae mature from early June until late July; pupation lasts about ten days. There is one generation a year. It seems probable that all Canadian species are, like *I. sulphurea*, univoltine. In *I. exauspicata*, there are five larval instars; the larval stage lasts about 30 days. In several species (*I. decorata*, *I. anataria*, *I. exauspicata*, *I. denticulodes*, *I. bitactata*, and *I. occiduaria*) the pupal period may extend from 7 to 28 days with the average about 17 days.

External Morphology

The larvae of *Itame* are typical loopers with one pair of legs on each of the sixth and last abdominal segments and no conspicuous swellings or tubercles on the head, thorax or abdomen. The crochets of the abdominal legs are biordinal and arranged in a continuous mesoseries in the fifth instar but in a broken mesoseries in the earlier instars. The anal plate is rounded at the posterior end (Figs. 22, 25, 27 to 33 and 35). The hypoproct and paraprocts are of moderate length; in *I. ribearia* the hypoproct is about 0.5 mm. in length and 0.5 mm. in diameter at the base (Fig. 34). The cuticle or integument of the head is smooth in the ultimate (the fifth stage where definitely determined) but rugulose in penultimate stage larvae. The cuticle of the thorax and abdomen is smooth. There are from four to six annulets on each of the anterior abdominal segments.

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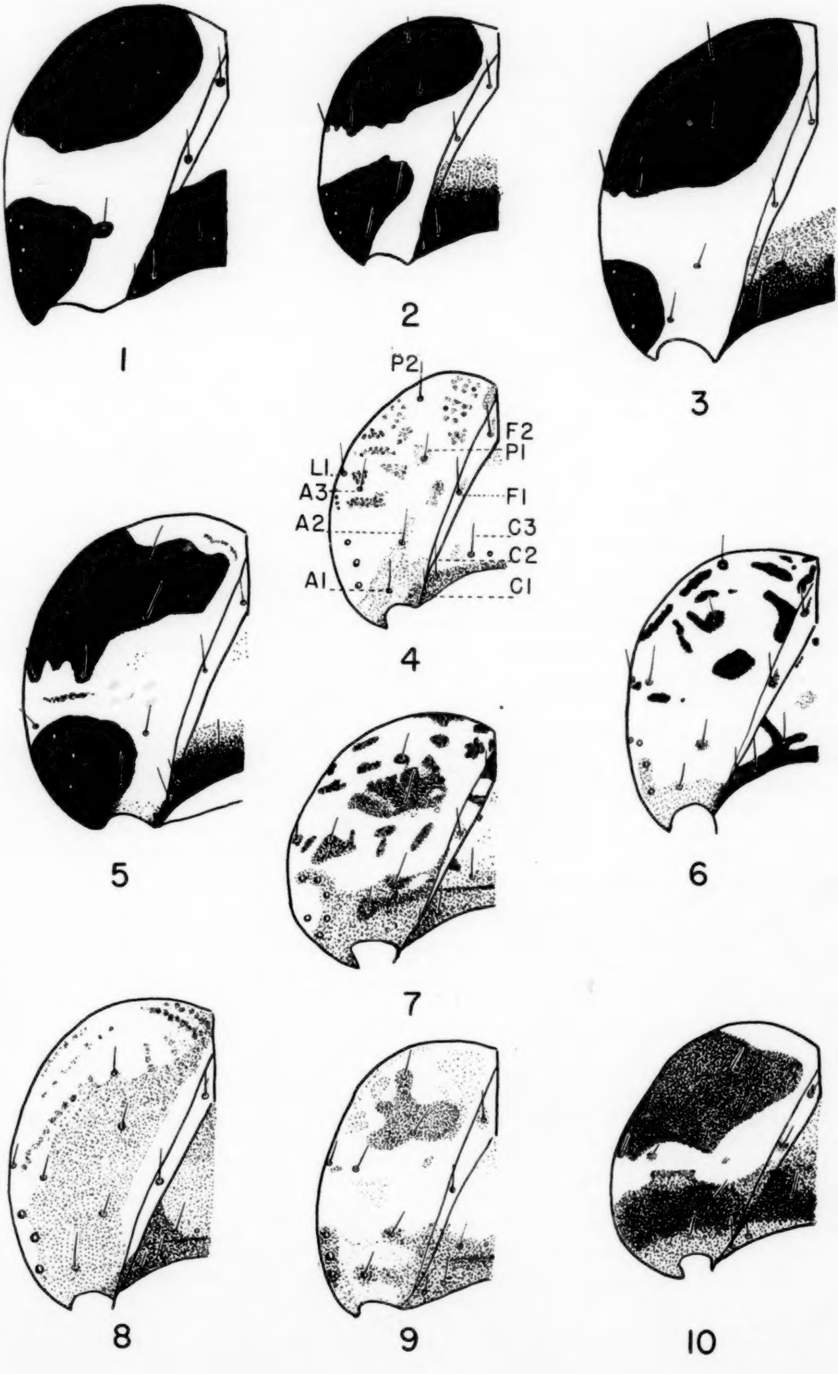
Figs. 1-10. Colour patterns of head capsules of ultimate instar larvae of *Itame*: 1, *evagaria*: 2, *andersoni;* 3, *ribearia;* 4, *brunneata;* 5, *occiduaria;* 6, *exauspicata;* 7, *anataria;* 8, *bitactata;* 9, *decorata*; 10, *denticulodes*.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The setae, which are long, pointed, and dark brown in colour, arise from small tubercles. The setal patterns are quite uniform in the ten species examined. On the first abdominal segment, setae SV 1, SV 2, and V 1 are in alignment (Fig. 18) and seta L4 is present on abdominal segments two to five inclusive (Figs. 19 and 23). There are four setae on the outer aspect of each ventral abdominal leg (Fig. 20). The setae D 1 are always posterior to a line joining setae SD 1 on the anal plate (Fig. 31).

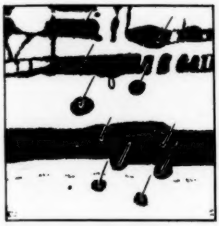
The larvae of this genus are characterized by interesting colour patterns. Most of these patterns are in black or brown but in some species they are in green: *I. sulphurea* (Pack.) (Franklin, 1948) and *I. coortaria enigmata* B. and McD. (Rupert, vide Forbes, 1948). In one species, *I. bitactata,* the larvae may be brown or green. The brown phase larvae have a dark bar at the base of the clypeus. The markings on the parietals vary from small brown to large black patches (Figs.1-10). The basic pattern of the body consists of a number of dark lines with the main ones in the subdorsal, supraspiracular, and subventral regions and paler ones in the middorsal, midventral, and adventral regions (Figs. 11-16 and 21, 23, 24, 26). There is intraspecific variation in the intensity of the markings and in the detailed arrangement of the patterns which vary from specimen to specimen and from one side of the individual to the other. Such variation is not great enough to prevent the separation of the larvae on the basis of colour characters.

One can place these larvae in the subfamily Ennominae because: they have but one pair of ventral abdominal legs; they have seta L 4 present on abdominal segments two to five inclusive; they have from four to six annulets on each of the anterior abdominal segments; on the first abdominal segment setae SV 1, SV 2 and V 1 are in alignment; and setae D 1 are always posterior to the line joining setae SD 1 on the anal plate. The smooth cuticle, rounded anal plate, setal patterns, and the arrangement of lines or rows of spots indicate that the larvae are closely related to larvae of *Semiothisa.* From the latter the larvae of *Itame* can be separated by differences in time of feeding and in colour pattern. The larvae of *Itame* feed in the early spring and early summer and usually have colour patterns of black or brown markings while the larvae of *Semiothisa* feed in the late summer and early fall (McGuffin, 1955) and usually have colour patterns of green lines on the thorax and abdomen (McGuffin, 1943, 1947).

Key to Mature Larvae of *Itame*

1. Five black patches on the head: two ocellar, two parietal and one clypeal (Figs. 1, 2, 3, 5) 2
   Many dark spots, usually, on the head (Figs. 4, 6, 7, 9) but pattern may be more general (Figs. 8 and 10) 3
2. Subventral stripe continuous on third abdominal segment and of uniform width throughout (Figs. 11 and 13); head 1.70 to 1.90 mm. in width 3
   Subventral stripe not continuous on third abdominal segment and not of uniform width throughout (Figs. 12 and 14); head 1.90 to 2.28 mm. in width 4
3. Setae of anal plate on U-shaped black patch (Fig. 22) .... *evagaria*
   Setae of anal plate on several, more or less connected, patches (Fig. 25) .... *andersoni*
4. One long, black patch in subventral region on third abdominal segment (Fig. 14); setae of anal plate set in more or less separate patches of colour (Fig. 33) .... *occiduaria*
   Two irregularly-shaped black patches in the subventral region (Fig. 12); setae D1, L1, and D2 in the same patch of colour on anal plate (Fig. 35) .... *ribearia*

Figs. 11-20. Colour and setal patterns of thoracic and abdominal segments of ultimate instar larvae of *Itame*: 11-16. Colour patterns of third abdominal segments of: 11, *evagaria;* 12, *ribearia;* 13, *andersoni;* 14, *occiduaria;* 15, *brunneata;* 16, *exauspicata;* 17-20. Setal patterns of *I. ribearia*: 17, prothorax and mesothorax; 18, first abdominal segment; 19, second abdominal segment; 20, sixth, seventh, eighth, ninth and tenth abdominal segments.



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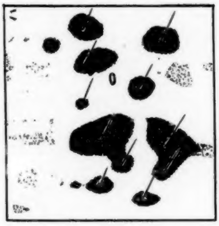

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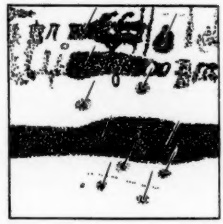

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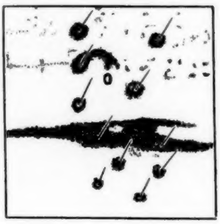

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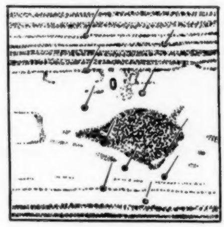

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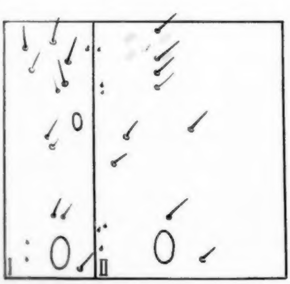

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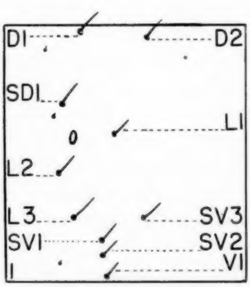

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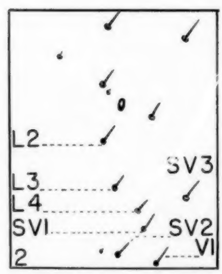

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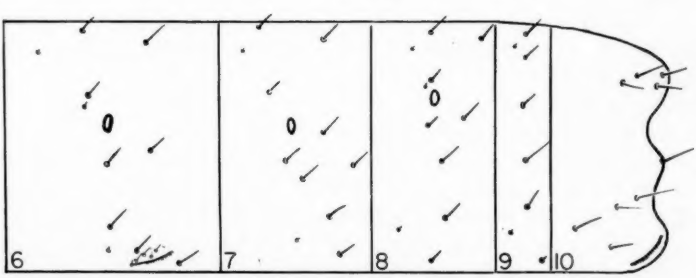

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5. Length of seta L1 on anterior abdominaly segments less than the length of dark patch around or ventrad of this seta (Figs. 15, 16, 24) 6
   Length of seta L1 on anterior abdominal segments greater than length or width of dark spot at its base (Fig. 26) .... *decorata*
6. Head with dark patch across lower clypeus and parietals and a smaller dark patch on each upper parietal (Fig. 10); dark dorsal markings on abdomen broad and irregular (Fig. 24) .... *denticulodes*
   Head with many dark spots (Figs. 4, 6, 7, 8); dorsum of abdomen marked with fine lines (Figs. 15, 16, 21, 23) 7
7. Large dark subspiracular patch touches seta L3 on third abdominal segment (Figs. 16 and 21) 8
   Large dark subspiracular patch does not touch seta L3 on third abdominal segment (Figs. 15 and 23) 9
8. Middorsal line continuous on anterior abdominal segments (Fig. 16); black patch at base of seta P1 on head not as broad as seta is long; conspicuous black cross on lower clypeus (Fig. 6) .... *exauspicata*
   Middorsal line broken on anterior abdominal segments (Fig. 21); brown patch at base of seta P1 on head at least as broad as seta is long; no black cross on lower clypeus (Fig. 7) .... *anataria*
9. Frons and adjacent parietal region paler, contrasting with darker parietals and clypeus (Fig. 8); lines often lacking on anterior portion of abdominal segments (Fig. 23); setal bases of anal plate dark (Fig. 32) .... *bitactata*
   Frons and adjacent parietals and clypeus concolorous (Fig. 4); lines continuous on abdominal segments (Fig. 15); setal bases of anal plate light (Fig. 29) .... *brunneata*

Discussion of Species

Itame ribearia (Fitch)

This insect may become a serious pest where currents and gooseberries are grown commercially. Many reports of damage can be found in the Canadian Insect Pest Review. Craighead (1950) includes it in the forest insects.

No. of larvae studied: 9 (preserved).

Description: Ultimate instar: Head white with black spots (Fig. 3); body white or pale with prominent black spots in rows on the subdorsal, supraspiracular and subventral regions (Fig. 12). Anal plate white with black patches or spots (Fig. 35). Thoracic legs black; abdominal legs pale with black spots and patches.

The penultimate instar is much the same in colour pattern as the ultimate.

Measurements: In penultimate instar, width of head 1.50 mm.; body 12 mm. in length and 1.50 mm. in width. Crochets on ventral abdominal leg number 16, in two groups. In last instar, head width is 1.90 to 2.28 mm.; body 11 to 25 mm. in length and 1.50 to 3.00 mm. in width. On ventral abdominal leg the crochets number from 25 to 28 in one group.

Food plants: Foliage of currants and gooseberries (*Ribes* spp.).

Distribution: Quebec to New Jersey, west to Colorado and Alberta.

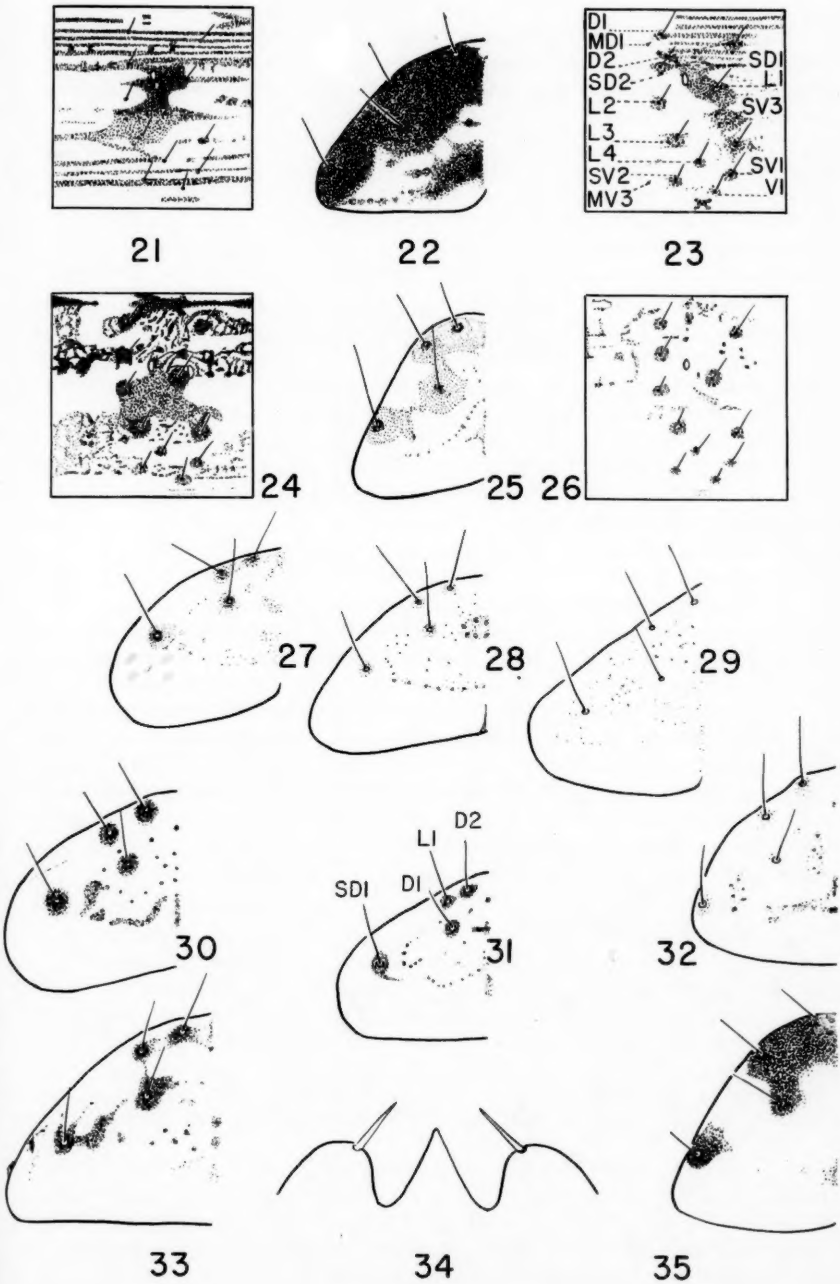
Parasites: There is one hymenopterous and one dipterous parasite of this insect; these are *Meteorus hyphantriae* Riley and *Compsilura concinnata* Meig. (Schaffner and Griswold, 1934).

Itame evagaria (Hlst.)

No. of larvae studied—5 (preserved).

Description: Penultimate instar: Head pale with black patches, much the same as in the final instar. Body pale with grey lines in subdorsal, supraspiracular and a grey stripe in the subventral regions. Anal plate as in ultimate stage larvae.

Figs. 21-35. Colour patterns of third abdominal segments and anal plates of ultimate instar larvae of *Itame*: third abdominal segments: 21, *anataria;* 23, *bitactata;* 24, *denticulodes;* 26, *decorata;* and anal plates: 22, *evagaria;* 25, *andersoni;* 27, *denticulodes;* 28, *anataria;* 29, *brunneata;* 30, *exauspicata;* 31, *decorata;* 32, *bitactata;* 33, *occiduaria;* 35, *ribearia;* 34, hypoproct and paraprocts of *I. ribearia.*


D1
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Ultimate instar: Head whitish with black patches (Fig. 1). Body pale with black spots in lines in subdorsal and supraspiracular areas; subventral stripe blackish (Fig. 11). Anal plate with large black patch posteriorly (Fig. 22). Thoracic legs blackish; abdominal legs pale with black spots.
Measurements: In antepenultimate instar, the head width varies from 0.63 to 0.68 mm. In penultimate instar width of head is 1.14 mm. and body varies from 8 to 13 mm. in length. On the ventral abdominal leg the crochets number 12 to 14, in two groups. In the last instar the width of the head is from 1.81 to 1.90 mm. and the length of the body is about 14 mm. On the ventral abdominal leg the crochets number 20 to 27, in one group.
Food plants: Gooseberry and blueberry (*Vaccinium* spp.) foliage.
Distribution: Ontario, Quebec, New Hampshire, New York, Pennsylvania, Wisconsin, Illinois, Iowa and Kansas.

Itame brunneata (Thunb.)
No. of larvae studied–6 (preserved).
Description: Ultimate instar: Head pale brown, spotted with small brown dots (Fig. 4). Body yellow, lined with brown (Fig. 15). Anal plate pale brown with fine, brown dots scattered over it (Fig. 29). Legs pale brown.
Measurements: Width of head 1.56 to 1.67 mm. Body 13 to 18 mm. in length and 2.3 to 2.4 mm. in width. Crochets on ventral abdominal leg number 22 to 24.
Food plants: Blueberry.
Distribution: Holarctic.

Itame andersoni Swett
No. of larvae studied: 6 (preserved).
Description: Ultimate instar: Head white with black patches (Fig. 2); body pale with two rows of fine, black dots in subdorsal and supraspiracular regions and a black stripe in the subventral area (Fig. 13). Greyish patches at setal bases on anal plate narrowly joined to form one irregularly-shaped patch (Fig. 25). Thoracic legs blackish; abdominal legs pale with black spots.
Measurements: Width of head 1.71 to 1.88 mm. Body 14 to 17 mm. in length and 1.7 to 2.4 mm. in width. On the ventral abdominal leg the crochets number from 24 to 26.
Food plants: Blueberry (Ferguson, 1955).
Distribution: Nearctic.

Itame occiduaria (Pack.)
No. of larvae studied–3.
Description: Ultimate instar: Head pale or white with black patches (Fig. 5). Body pale grey with rows of small spots in subdorsal and supraspiracular regions and a broad black line in the subventral area (Fig. 14). Anal plate whitish with black dots and patches (Fig. 33). Thoracic leg black; abdominal legs pale with black spots.
Measurements: Head 1.90 to 1.94 mms. in width; body 14 to 17 mm. in length and 1.8 to 2.3 mm. in width. On the ventral abdominal leg the crochets number 26 to 27.
Food plants: The food plants are dwarf or bog birch (*Betula glandulosa* Michx.), shrubby cinquefoil (*Potentilla fruticosa* L.), limber pine (*Pinus flexilis* James), and trembling aspen (*Populus tremuloides* Michx.). McDunnough (1924) reared *I. occiduaria* from *Amelanchier*; Ferguson (1953) reports it on *Ribes* and indicates that Criddle found this species on *Arctostaphylos*.
Distribution: Western North America; occasionally found in the eastern part of this continent (Ferguson, 1953).

Itame anataria (Swett)

No. of larvae studied–25.

Description: (Description of one larva, Forest Insect Survey, record No. 53 Alberta 61A, larva No. 10, collected at Harmon Valley, Alberta, on May 29, 1953, on scrub birch; this larva was described June 6 and June 15; it pupated on June 23 and a female emerged on July 11).

Antepenultimate instar: Head 0.76 mm. in width; body 9.0 mm. in length and about 1.0 mm. in width. Head pale with black herring-bone markings on parietals; clypeus immaculate. Body pale grey with geminate black middorsal, subdorsal, supraspiracular, subventral, and midventral lines. Spiracular line white with spiracles in black patches. Thoracic legs black and abdominal legs dark grey.

Penultimate instar: Head 1.30 mm. in width; body 13 mm. in length. Head and body much the same colour as antepenultimate instar; head with brown markings on the clypeus.

Ultimate instar: Head 1.90 mm. in width; body 18 mm. in length and 2.0 mm. in width. Head pale grey with brown herring-bone patterns on upper parietals; lower face brownish with a pale transverse bar. Clypeus with fine brown dots on it. Body pale grey with geminate lines of third stage tending towards solid stripes. Middorsal line broken between Dorsal setae.

Variations: Ground colour of the head (Fig. 7) varies from pale grey to pale brown and of the body (Figs. 21, 28) from pale grey to grey-green. Markings on head and body brown to black.

Measurements: The head widths of the antepenultimate, penultimate, and ultimate instars are: 0.76 to 0.80 mm.; 1.14 to 1.30 mm. and 1.80 to 2.00 mm., respectively, and the lengths of the body in these instars are 7.0 to 9.0 mm., 8.0 to 13.0 mm. and 13.0 to 22.0 mm. The crochets of the ventral abdominal leg number 10 in the penultimate instar and 20 to 30 in the last instar.

Food plants: Shrubby cinquefoil (*Potentilla fruticosa* L.), birch (*Betula* spp.), willow (*Salix* spp.); and poplar (*Populus* spp.).

Distribution: Nearctic.

Parasites: Four species of hymenopterous parasites have been reared from this insect by the Forest Insect Survey in Calgary; these are: *Microgaster* sp., *Casinaria forcipata* Wly., *Campopletis* sp., and *Apanteles* sp.

Itame exauspicata (Wlk.)

No. of larvae studied–16.

Description: (Description of two larvae, Forest Insect Survey, record No. 45 Winnipeg 53C, larvae Nos. 2 and 3, collected at Fort Garry, Manitoba, on June 6, 1945, on willow; the larvae were described June 19 and June 27, pupated July 2 and 5; a male emerged July 20 and a female, July 21).

Fourth instar: Width of head 1.28 mm., body 12 mm. in length and 1.0 mm. in width. Head white with black spots arranged in herring-bone pattern; clypeus white with dark dot in upper corner and black cross at base. Body white with black lines between yellow-white spiracular and black middorsal lines. Black lines between spiracular and pale midventral line, and a black patch below spiracle. Prothoracic plate concolorous with body; anal plate white with black dots on it. Thoracic legs black, with white ring on each coxa; abdominal legs pale grey.

Fifth instar: Head 1.90 mm. in width; body 25 mm. in length and 2.4 mm. in width. Upper part of head white with markings as in previous instar; lower

parietal area yellowish. Body white with yellow suffusion in dorsum and intersegmental areas; lines much as in previous instar.

Variations: Head with brown spots (Fig. 6) which may, or may not, be in a herring-bone arrangement along the epicranial stem and a conspicuous black cross on the lower part of the clypeus. Body (Fig. 16) and anal plate (Fig. 30) with dark markings.

Measurements: The head width for the first instar, 0.32 mm.; for the second, 0.43 mm.; for the third, 0.65 to 0.85 mm.; for the fourth, 1.08 to 1.28 mm.; and for the fifth, 1.73 to 2.12 mm. In the fourth instar the length of the body is about 12 mm.; in the last instar the length is 19 to 25 mm. In the last instar the crochets of the ventral abdominal leg number 20 to 30.

Food plants: The larvae of *I. exauspicata* have several hosts. Forbes (1948) states that willow (*Salix* spp.) is the food plant. Jones (1951) mentions trembling aspen (*Populus tremuloides* Michx.) and birch (*Betula* spp.) as food plants. Data gathered at Ottawa, Winnipeg, and Calgary record that the larvae also eat alder (*Alnus* spp.), white elm (*Ulmus americana* L.), bur oak (*Quercus macrocarpa* Michx.), cherry (*Prunus* sp.), and ironwood (*Ostrya virginiana* (Mill.) K. Koch).

Distribution: Nearctic. Not reported by Ferguson (1955) in Nova Scotia.

Parasites: Only one species of parasite has been recorded from this host: *Rogas* sp.

Itame bitactata (Wlk.)

No. of larvae studied—14.

Description: There are two colour phases, a brown and a green, in this species, somewhat the same as in *Semiothisa sexmaculata* (Pack.) (McGuffin, 1947).

(Description of a brown phase larva, Forest Insect Survey, record No. 52 Alberta 635E, collected at Waterton Lakes, Alberta, June 15, 1952, on alder; this larva was described June 27, pupated July 5, and a male emerged July 22).

Ultimate instar: Head 1.71 mm. in width; body 20 mm. in length and 2.0 mm. in width. Head pale brown with a vertical brown bar on the clypeus. Body yellow in ground colour with two geminate brown lines between the geminate brown middorsal line and the spiracular region. Spiracles in pale areas with yellow patches anterior and brown obliques posterior to the spiracles on the anterior segments. Midventral line geminate, brown. On the venter there are brown transverse bands which connect the brown obliques. Thorax and posterior end of body brownish. Plates concolorous with adjacent areas of body; legs brownish.

(Description of a green larva, Forest Insect Survey, record No. 54 Alberta 436D, larva No. 4, collected on the Kananaskis Forest Experiment Station, Seebe, Alberta, on July 6, 1954 on alder; this larva was described on July 15, pupated July 19, and a female emerged July 31).

Penultimate instar: Head 1.27 mm. in width. Head and body greenish, with pale lines on the latter.

Ultimate instar: Width of head 1.90 mm. on July 11 and 1.98 mm. on July 15. Body 20 mm. in length and 3.0 in width. Head pale russet-green with no markings. Body green with geminate, white middorsal line, white lateral line, trace of a white supraspiracular line and yellow spiracular stripe. Venter green.

Variations: The larva of *I. bitactata* usually has a light frons contrasting with darker parietals and clypeus (Fig. 8); dark obliques usually present posterior to the spiracles (Fig. 23) but these may be absent in green phase larvae.

Measurements: The width of the head, in the penultimate instar, is 1.27 to 1.33 mm. and in the ultimate instar 1.71 to 2.12 mm. The length of the body varies from 12 to 18 mm. in the penultimate instar and from 13 to 20 mm. in the ultimate

instar. The crochets of the ventral abdominal leg, in the last instar, number from 29 to 32.

Food plants: Alder (*Alnus* spp.) and gooseberry (*Ribes* spp.). In one case an adult was reared from a larva collected on white birch (*Betula alba* L.). It may be of interest to point out here that this and the two following species, *I. denticulodes* and *I. decorata,* have been collected in one sample from gooseberry.

Distribution: Nearctic.

Parasites: One hymenopterous parasite, *Rogas* sp., has been reared from *I. bitactata.*

Itame denticulodes (Hlst.)

No. of larvae studied–10.

Description: (Description of one larva, Forest Insect Survey record No. 52 Alberta 345B, collected at Star Creek, near Coleman, Alberta, on June 1, 1952, on gooseberry; the larva was described June 7, pupated June 14, and a male emerged July 9).

Ultimate instar: Width of head 1.90 mm. Body 20 mm. in length and 1.80 mm. in width. Head grey with lower clypeus, ocellar regions and lower parietals dark grey. On the upper part of each parietal there is a large dark grey spot. Body grey; middorsal line geminate grey, obscured by yellow in places; lateral stripe pale orange. Supspiracular stripe grey; subspiracular stripe pale orange, with a black patch below each spiracle. Venter pale yellowish with geminate grey midventral line.

Variations: All specimens examined were similar in colour patterns (Figs. 10, 24 and 27).

Measurements: Width of head 1.95 to 2.09 mm.; body 10 to 22 mm. in length and 1.80 to 3.00 mm. in width. Crochets on ventral abdominal leg number from 26 to 29.

Food plants: Gooseberry.

Distribution: Southwestern Alberta and the southern interior of British Columbia (Bowman, 1951; Jones, 1951).

Itame decorata (Hlst.)

No. of larvae studied–3.

Description: (Description of one larva, Forest Insect Survey, record No. 52 Alberta 822B, collected at the summit of the West Porcupine Hills, Crows Nest Forest Reserve, Alberta, on June 28, 1952, on gooseberry; the larva was described on July 10, pupated on the same day, and a male emerged July 23).

Ultimate instar: Width of head not recorded. Body 15 mm. in length and 2.0 mm. in width. Head pale brown, with a brown band across the lower part of the face and a dark brown spot on the upper part of each parietal. Body pale grey with poorly-marked geminate brown middorsal line. Dorsum, sides and venter lined with purplish lines. Lateral line pale orange, broken; subspiracular yellowish.

Variations: No marked deviations from this description have been noted; the head (Fig. 9), third abdominal segment (Fig. 26), and anal plate have been illustrated.

Measurements: Width of head 1.77 to 1.90 mm. Body 16 to 20 mm. in length and 2.3 to 3.0 mm. in width. On the ventral abodminal leg the crochets number from 23 to 28.

Food plants: Gooseberry.

Distribution: Southern Alberta and southern British Columbia (Bowman, 1951; Jones, 1951).

Acknowledgments

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Linear Increment in Width of the Head Capsule of two Species of Sawflies[1]

By A. W. Ghent[2]

Interest in the growth of insect head capsules was aroused by the observation of Dyar (2) that for a number of lepidopterous larvae the ratio of the width of the larval head capsule in a given instar to that in the following instar tends to be constant throughout development. This observation, generally known as "Dyar's Law" or "Dyar's Rule", has proven valid for many lepidopterous larvae, for which it was proposed. Many attempts have been made to apply Dyar's Rule to insects of other orders. Various authors, notably Miles (6) and Taylor (7), have considered the application of Dyar's Rule to sawfly larvae, and although they report some inconsistencies, they conclude that the rule is useful if its application is restricted to checking upon the number of feeding instars. The head capsules of non-feeding prepupal sawfly larvae are generally of the same size as those of the last feeding instar, so that this stage is not expected to satisfy Dyar's Rule.

During a study (4) of the feeding behaviour of the jack-pine sawfly, *Neodiprion americanus banksianae* Roh., analysis of data on the size of feeding groups during the various larval instars required that the average width of the head capsule in each instar be known. Measurements obtained during this study are given in Fig. 1 as separate frequency distributions equally spaced to represent the five instars. The mean width at each instar is shown by small crosses placed at the same height above each x-axis. A dotted line has been drawn between these means, and from inspection of this line, or from consideration of the differences between successive instars also given in the figure, it can be appreciated that head capsule growth in this species is almost precisely linear.

All larvae were killed in 70 per cent alcohol before measurement. From 15 to 20 family colonies are represented in the total of 268 larvae measured during this study, and all were reared under the same conditions at approximately the same time. Both male and female larvae occurred in these colonies in approximately equal numbers, so that both are represented in the samples for the first four instars. Since there is no indication of a bimodal distribution to the measurements of these four instars, there is probably either no, or very little, difference between the sexes in head capsule width. Male larvae pass directly from the fourth instar into the prepupal stage, so that only female larvae appear in the sample for fifth instar.

A comparison of the goodness of fit obtained with Dyar's Rule and with a linear regression line fitted to the means by the method of least squares is given in Table 1. Consideration of the per cent errors of the two sets of predicted values is sufficient to show that the straight line gives a substantially more accurate description of the data. The average ratio of increment between the five means taken in successive pairs was used in the calculation of predicted values by Dyar's Rule. The use of an average growth ratio, suggested by Imms (5) and others and commonly adopted, ensures the best possible fit of the predicted to the observed measurements, but contrary to a major purpose of

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[1]Based in part on data included in a thesis submitted to the University of Toronto in partial fulfilment of the requirements for the degree of Master of Arts. These data were gathered during studies of the jack pine sawfly, conducted at the Department of Zoology, University of Toronto, and supported by a fellowship donated by the Spruce Falls Power and Paper Co., and by a Research Council of Ontario Scholarship.

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TABLE I

A comparison of the agreement between the observed head-capsule widths of *Neodiprion americanus banksianae* (Roh.), and those calculated from (i) Dyar's Rule, (ii) linear regression

Instar	Observed width	Dyar's Rule		Linear Regression	
		Calculated width	Per cent error	Calculated width	Per cent error
I	0.58 mm.	—	—	0.568	2.1
II	0.84	0.760	9.5	0.858	2.1
III	1.15	0.996	13.4	1.148	0.2
IV	1.44	1.306	9.3	1.438	0.1
V	1.73	1.712	1.0	1.728	0.1

the rule, this method appears to be of little value as an indication of missing instars.

Both Miles (6) and Taylor (7) offer examples of measurements of sawfly head-capsule growth in satisfactory agreement with Dyar's Rule. However, Friend (3), describing a birch leaf-mining sawfly, *Fenusa pusilla* (Lep.) (=*pumila* Klug), dwells at some length upon the limitations of Dyar's Rule when applied to head-capsule measurements of this species. Although he calculates the per cent errors of the means predicted by Dyar's Rule and suggests that errors of this size limit the usefulness of the rule, he offers no alternative formula to describe his data. Calculation of the differences between successive means indicated that the growth of the head capsule of this insect was also almost precisely linear. Friend's data on *F. pusilla* have been reproduced in Table 2 and have been treated in the manner described for *N. a. banksianae* data in Table 1. Consideration of the per cent errors of the two sets of predicted values indicates that again the simple straight line gives a substantially more accurate description of the data.

The application of Dyar's Rule yields an exponential series of the form $a + a.x + a.x^2 + \ldots\ldots + a.x^{n-1}$, where "n" is the number of instars, "x" is the growth ratio, and "a" is the width of the first instar head capsule. Although exponential growth in width of the head capsule involves increasingly larger additions at each successive moult, this type of growth is readily understood if one considers that the *ability to grow*, as expressed by the ratio of increase between successive instars, remains constant. The amount of increase at any given moult is directly dependent upon the size of the head capsule previously attained. Linear growth, on the other hand, involves the addition of a constant amount to the width of the head capsule at every moult, so that the ratios of increase between successive instars form a declining series. The amount of increase is independent of the given state, and decreases in relation to growth already attained. In this latter consideration it must be remembered that growth in width of the head capsule represents the increment in only one dimension of a three-dimensional structure, and that growth in other dimensions may be disproportionate to growth in width. For this reason one must entertain the possibility that growth *in toto*, as given by the volume of the head capsule, may still follow an exponential series even though growth in width is linear. The problem of volumetric growth of insect head capsules offers attractive possibilities

TABLE II

A comparison of the agreement between the observed head-capsule widths of *Fenusa pusilla* (Lep.)*, and those calculated from (i) Dyar's Rule*, (ii) linear regression

Instar	Observed width	Dyar's Rule		Linear Regression	
		Calculated width	Per cent error	Calculated width	Per cent error
I	0.293 mm.	—	—	0.291	0.8
II	0.416	0.386	7.2	0.420	1.1
III	0.552	0.510	7.6	0.550	0.3
IV	0.680	0.674	0.9	0.679	0.03

*Observed head-capsule widths, and theoretical widths calculated from Dyar's Rule, taken from Friend (3). Observed widths are averages of from 124 to 415 measurements per instar.

as a fundamental study in growth phenomena, and its investigation might well clarify the many discrepancies which have been noted by various workers who have attempted to apply Dyar's Rule. This approach appears to have been greatly neglected, possibly because the problems of measurement of head-capsule volume are more difficult, and because Dyar's Rule has directed so much attention to the growth in width of insect head capsules.

In the application of mathematical formulae to the description of growth data, errors may arise either because the data are inadequate, or because the particular growth law applied is inappropriate. A simple example of inadequate data is afforded by either a linear or an exponential series in which values are missing at one or both extremities. The remaining values still form a continuous series in which each term is properly related to the next, and no growth law, however appropriate, can demonstrate that the series has not been sufficiently extended. For this reason, the observer can only rely on careful rearing to establish first and last instars. Insufficient sampling and coarse measurement introduce inadequacies in the data more likely to affect the goodness of fit of an appropriate growth law, than to alter the apparent number of instars. Data given in Fig. 1 for second instar of *N.a.banksianae* may well reflect this type of error, for it can be appreciated from this figure that perfect linearity for the entire series would have been approached if second instar had averaged 0.86 mm. instead of 0.84 mm., a possibility well within the errors involved in a sample of only 29 insects.

Examples of errors arising from the application of an inappropriate growth law could be given either by applying Dyar's Rule to data showing linear regression, or by treating as linear, data actually in agreement with Dyar's Rule. In view of the demonstrated occurrence of linear increment in width of the head capsule in two well-separated genera, it is possible that the phenomenon may be of more frequent occurrence throughout the sawflies. It is therefore worth while to examine certain errors inherent in the attempt to fit an exponential series such as that predicted by Dyar's Rule to data showing linear regression. The data for *N.a.banksianae* permit the demonstration of three types of error that may arise, each associated with a particular method of calculating Dyar's Rule.

The first of these again involves inadequate data. If the penultimate term of a short linear series is missing, the series is liable to appear exponential. For

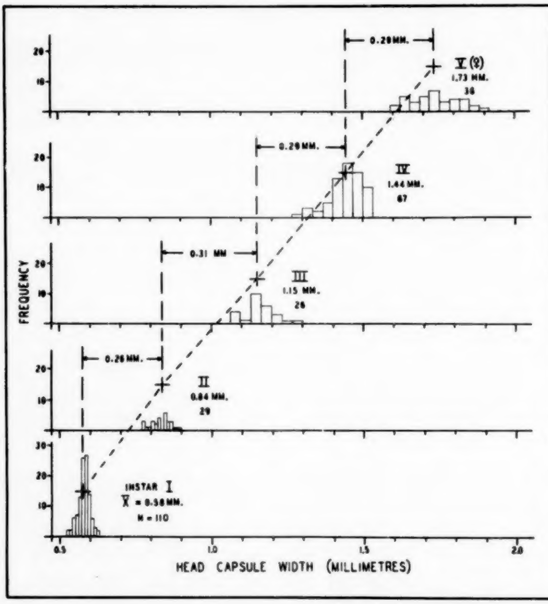

Fig. 1. Frequency distributions of head-capsule measurements of the jack-pine sawfly, *Neodiprion americanus banksianae* Roh., plotted in micrometer divisions above a millimetre scale. Wider histogram bars for instars III, IV, and V reflect the necessary use of a lower magnification to accommodate the larger head capsules in the microscope field.

example, if the width of the fourth-instar head capsule is deliberately discarded from the data for *N.a.banksianae* in Table 2, an average ratio of growth from first to second, second to third, and *third* to *fifth* instar of 1.44 is obtained, and with this, the series 0.58 (accepted), 0.84, 1.20, and 1.73 is predicted. Although Dyar's Rule, calculated from the average growth ratio, has predicted the four instars remaining in the data with an error of only 4.3 per cent in one instar, such precision is of little value when it fails to indicate a deliberately "missed" instar. The actual ratios of increase between successive instars, from first to fifth, for *N.a.banksianae* form the following declining series: 1.45, 1.37, 1.25, and 1.20. These ratios clearly lack any central tendency, so that their "average" is immediately suspect. If the penultimate instar is deliberately discarded, the effect of averaging growth ratios between the remaining instars is to ensure that the apparent number of moults indicated by the data is confirmed by the predicted series. For this reason, Dyar's Rule, calculated from the average growth ratio of even an apparently exponential series, cannot be relied upon to provide a check against missing instars.

In a true exponential series one should be able to take a ratio at either the beginning or the end and work either forward or backward to predict the remaining values. Attempts to do this furnish examples of the other two types of error inherent in the application of an exponential growth law to data showing linear regression. Assume that an investigator had obtained the data for *N.a.banksianae* presented in Table 1, and was confident only that the last two measurements were correctly applied to the last two instars. From these he would calculate a ratio of 0.832, with which he would attempt to work back-

wards to check the earlier instars by Dyar's Rule. The following series would be predicted: 0.57, 0.69, 0.82, 0.99, 1.19, followed by the accepted values of 1.44 and 1.73. He might accept the predicted values of 0.57, 0.82 and 1.19 as lying tolerably close to the values of 0.58, 0.84 and 1.15 observed, but he could only conclude that the other two values in the series, 0.69 and 0.99, represented "missing" instars for which he still must search.

On the other hand, assume that this investigator was confident only that the first two measurements were correctly applied to the first two instars. From these he would calculate a ratio of 1.45, with which he would attempt to work forward to predict the remaining instars. The following series would then be predicted: 0.58, 0.84, 1.22, and 1.76, the first two values representing his accepted measurements. He might accept the final value of 1.76 as lying tolerably close to his observed value of 1.73, but he could only assume that his observed values of 1.15 and 1.44, lying fairly evenly on either side of the predicted value of 1.22, indicated that his measurements had been artifically divided to represent an extra instar. Perhaps more serious still, had he actually lumped the data for third and fourth instar, and obtained a mean somewhere in between, he would be well satisfied by the apparent agreement with Dyar's Rule, and would not be encouraged to re-examine his measurements.

It is noteworthy that Taylor (7), in reproducing an extensive list of sawfly head-capsule measurements made by Dyar himself, includes several that appear precisely linear, and others that are very nearly so. Although Dyar did not give the number of individuals in his samples, Taylor supposes this to be at best a few, and in many instances only a single larva. For this reason, no rigorous conclusions can be drawn for any of the 46 species which Taylor lists. However, the data for *Pontania gracilis* Marlatt, *Periclista purpuridorsum* Dyar, *Atomacera desmodii* Dyar, *Pteronus ostryae* Marlatt, *Nematus similaris* Nort., *N. mendicus* Walsh, and *N. dorsivittatus* Cress. suggest that the growth of the head capsule of these sawflies is linear or nearly so.

Of particular interest in Taylor's list are the data for *Pteronus ostryae*. The actual measurements form the following precisely linear series: 0.40, 0.70, 1.00, 1.30, and 1.60. This insect evidently begins and ends larval life with a head capsule slightly narrower than *N.a.banksianae*, but grows at about the same rate, 0.30 mm. per moult. Taylor has applied Dyar's Rule by working backward from the ratio calculated for the last two values of the series, in a manner similar to that of an earlier example in this paper. From these last two measurements he calculates a ratio of .812, and with this he predicts the following series: 0.46, 0.57, 0.70, 0.86, 1.06, followed by the accepted values of 1.30 and 1.60. As in the case of our hypothetical investigator, Taylor is willing to accept that the predicted values of 0.46, 0.70, and 1.06 are in agreement with the observed values of 0.40, 0.70, and 1.00, but is at a loss to know what to do with the values of 0.57 and 0.86 interpolated in the series. For these, and for similar discrepancies throughout the list of measurements, Taylor suggests the following possible explanations:

1. Dyar missed the stage and was unaware of it.
2. The measurement was inaccurate.
3. The larva measured was abnormal or exceptional, or simply exhibited natural variation from an unknown mean.
4. Typically, the Rule does not hold—
   a. With sawflies as a group.
   b. With this particular species.
   c. Except when averages of instar measurements are available.

Let us examine these possibilities in relation to the data for *P. ostryae*. In the first place it is unlikely that Dyar missed an instar, for if one considers the rate of increase of the actual measurements, it is apparent that at no point in the series is there a gap where a missing instar might be placed. Secondly, the measurements undoubtedly involve some inaccuracy, and most certainly the series of zeroes in the second decimal place must represent an unjustified number of significant figures, rather than so remarkable a coincidence. But the measurements are probably accurate to the first decimal place, and at this level the average is not appreciably refined by increased sample size. Thirdly, if only one larva was followed throughout its growth, it was sufficiently normal to complete its development, and as Bliss and Beard (1) have shown, such a procedure is the most accurate when only a few insects are available. It is more likely, however, that each instar was represented by a different insect, in which case it is difficult to visualize all five larvae being so neatly abnormal as to bring their head capsule measurements to a precise straight line. Of Taylor's last three comments on the reliability of the Rule, one cannot say that the Rule does not hold with sawflies as a group, for many of the measurements which Taylor presents are in very close agreement with the values predicted by Dyar's Rule. Nor can one suppose that larger samples would do more than to provide a measure of the spread about the series already indicated, for the chance of any single measurement being correct to the first decimal place is preponderantly great. One is led, therefore, to the conclusion that throughout the sawflies there are particular species for which Dyar's Rule does not hold, since the growth in width of the head capsule of these sawflies is more accurately described by a linear regression line, than by the exponential series that Dyar's Rule predicts.

The existence of both linear and exponential growth patterns in head capsule width not only suggests the desirability of studies of the volumetric increment of insect head capsules, but points up the real nature of mathematical growth formulae. The "growth law" can do no more than describe a growth phenomenon, the nature of which must first be established by the most careful observation. Thus the uncritical application of Dyar's Rule, in a group such as the sawflies in which linear increment in head capsule widths may occur, can lead to inaccurate and misleading results. It is suggested that when head capsule measurements are used as a guide to the number of larval instars of sawflies, such measurements should be tested for linearity by a simple comparison of the difference between successive means before, Dyar's Rule is applied. In any event the investigator should place his greatest reliance upon direct inspection of the measurements, to see if, in relation to the general rate of increase of the series, there is at any point a discontinuity sufficiently great to indicate that a moult may have been entirely missed.

Summary

Data on the jack pine sawfly, *Neodiprion americanus banksianae* Roh., are presented which indicate the growth of the head capsule of this species to be almost precisely linear. Female larvae, moulting to a fifth feeding instar, continue the linear increment shown by mixed samples of male and female larvae in the first four instars. Published head capsule measurements of a birch leaf-mining sawfly, *Fenusa pusilla* (Lep.), are reproduced to show that, for this insect as well, the straight line gives a substantially more accurate description of head capsule growth than the exponential curve predicted by Dyar's Rule. Although moderately satisfactory results are obtained with Dyar's Rule if the average ratio of increment between successive pairs of means is used, this method is not reliable as a check on missing instars. Dyar's Rule, extrapolated from either end of the

linear series given by the head capsule measurements for *N.a.banksianae*, predicts means for non-existent instars. Examples of other sawflies for which head capsule growth is apparently linear are taken from the literature.

Acknowledgments

I wish to express my appreciation to C. E. Atwood of the Department of Zoology of the University of Toronto for his interest and encouragement in this study, and to R. M. Belyea and S. G. Smith of the Division of Forest Biology for their criticism of the manuscript.

I am particularly indebted to G. W. K. Stehr of the Forest Insect Laboratory, Sault Ste. Marie, for many stimulating discussions during the development of ideas expressed in this paper, and to C. Reimer, Statistical Research and Service Unit, Ottawa, for his careful assessment of the ideas and data presented.

Nomenclature

Since this paper was submitted, a revision of the *Neodiprion* sawflies by H. H. Ross (Forest Science 1(3):196-205, 1955) has changed the name of the jack pine sawfly from *Neodiprion americanus banksianae* Roh. to *Neodiprion pratti banksianae* Roh.

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(Received November 22, 1955)

A Technique for Pinning and Spreading Small Microlepidoptera[1]

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Identification of mounted specimens of Microlepidoptera is facilitated by good spreading technique. Although the larger specimens may be readily spread on a standard spreading board, small specimens present a problem. A special technique has been developed whereby small moths may be successfully spread and mounted on double-mount pins.

A piece of ½" or ¼" balsa wood covered with onion-skin paper serves as a spreading board. Narrow strips of onion-skin paper prove most satisfactory for wing coverings. The double mount consists of a "minuten nadel" with its blunt end set in the narrow edge of a block of balsa or polyporus, 2 x 3 x 10 mm., mounted on a No. 2 insect pin. The hole to accommodate the minuten nadel is made with a No. 0 insect pin.

The specimen to be pinned is placed dorsal side down on the board. A minuten nadel is grasped with a pair of forceps and, with the aid of a binocular microscope, the pointed end is inserted perpendicularly through the centre of the thorax, pinning the specimen lightly to the board. The pin with the transfixed specimen is raised very slightly to release the wings for spreading. The wing cover strips are placed in position and secured at one end with short common pins. Again using a microscope, the loose end of the cover strip is raised slightly while the wings are brought forward, but not pierced with a No. 00 or 000 pin. In each instance, the point of the pin is placed on the main vein of the wing, close to the thorax. First the fore wing is moved forward slightly to release it

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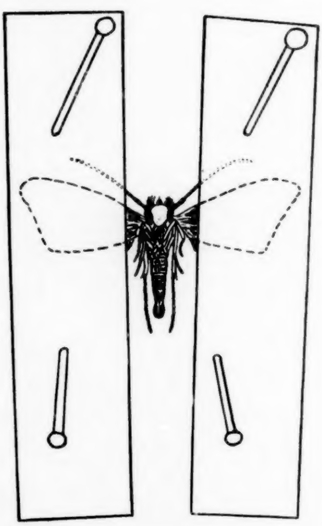

Fig. 1

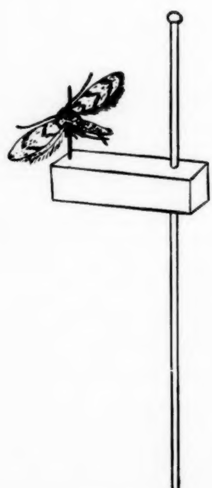

Fig. 2

Fig. 1. Specimen spread for drying.
Fig. 2. Specimen mounted on double-mount pin.

from its folded position under the body and the hind wing, then the pin is moved to the hind wing and both wings are brought forward simultaneously. When the wings are in the desired position the cover strip is pulled taut and secured with another common pin. Since the specimen is resting on its back the hind wings should overlap the fore wings slightly. It is emphasized that the wings must be brought forward with a minimum of effort to avoid excessive loss of scales.

When the specimen is dry, the cover strips are removed, and the specimen is lifted from the board with straight forceps. The insect is turned over, and the blunt end of the minuten nadel is eased through the hole previously made in the block of balsa or polyporus. A small amount of cement placed around the pin where it enters the mount will secure it firmly in place.

Although a certain degree of dexterity is essential, relatively inexperienced personnel have readily mastered this technique. Details will vary for different species and to suit different workers, but the general procedure will still apply.

Acknowledgments

The author is grateful for the constructive criticism offered by Dr. T. N. Freeman, Entomology Division, Ottawa, and the assistance of Miss F. Kelley in testing this technique.

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Dibrachys cavus (Wlkr.) (Hymenoptera: Pteromalidae), a New Parasite of the European Corn Borer, *Pyrausta nubilalis* (Hbn.) (Lepidoptera: Pyralidae), in Canada[1]

By Marcel Hudon[2]
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During the latter part of June, 1955, a larva of the European corn borer, *Pyrausta nubilalis* (Hbn.), dissected from overwintered corn stalks in experimental plots at St. Jean was observed to be parasitized by hymenopterous larvae. These were reared to the adult stage and were then identified by Dr. O. Peck, Entomology Division, Ottawa, as of *Dibrachys cavus* (Wlkr.). This parasite has only once been reported from North America (Blickenstaff *et al.*, 1953, p. 377) and once from Russia (Thompson, 1946, p. 517).

This is apparently the first record of this pteromalid as a parasite of *P. nubilalis* larvae in Canada.

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Some Mites of the Subfamily Phytoseiinae (Acarina: Laelaptidae) from Southeastern England, with Descriptions of New Species[1]

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For several years the author has been engaged in a study of the predacious mites of value in controlling the European red mite, *Metatetranychus ulmi* (Koch), in southeastern England. During this time, extensive collections of mites of the subfamily Phytoseiinae were made and several new species found. These are described here.

New species of Phytoseiinae have usually been described from female specimens only; the males have been frequently unknown. It is essential in ecological investigations to be familiar with both mature forms. During this study the males of some species of which the females had been described were collected and reared. Some of these have been described elsewhere (Chant, in preparation) and in this paper the male of *Typhlodromus bakeri* (Garman), 1948, is dealt with.

Also included is a list of the species of Phytoseiinae collected in England by the author during three years, including those that are being described as new.

Throughout the paper the nomenclature suggested by Garman (1948) for the dorsal and ventral setae of these mites is used. This has been discussed by Nesbitt (1951) and by Evans (1953).

Species of the Subfamily Phytoseiinae Collected in Southeastern England, 1953-55.

Genus *Typhlodromus* Scheuten, 1857
- *T. masseei* Nesbitt, 1951
- *T. tiliae* Oudemans, 1929
- *T. finlandicus* (Oudemans),1915
- **T. aberrans* Oudemans, 1930 (=*T. vitis* Oudemans, 1930, and *Kampimodromus elongatus* (Oudemans), 1930. See Chant, in preparation).
- *T. tiliarum* Oudemans, 1930
- *T. cucumeris* Oudemans, 1930 (=*T. thripsi* MacGill, 1939. See Evans, 1952).
- **T. polonicus* (Willmann), 1949, comb. nov.
- **T. marinus* (Willmann), 1952, comb. nov.
- *T. umbraticus* sp. n.
- **T. soleiger* (Ribaga), 1902
- *T. reticulatus* Oudemans, 1930
- *T. rhenanus* (Oudemans), 1905
- **T. bakeri* (Garman), 1948

Genus *Seiulus* Berlese, 1887
- *S. simplex* sp. n.

Genus *Amblyseius* Berlese, 1914
- *A. graminis* sp. n.

Genus *Phytoseius* Ribaga, 1904
- *P. macropilis* (Banks), 1909 (=*P. spoofi* (Oudemans). See Nesbitt, 1954).

Typhlodromus umbraticus sp. n.

Female.—Dorsal shield smooth and bearing 17 pairs of simple setae, arranged in a lateral row of nine, a dorsal row of six, and a median row of two pairs (Fig.

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*New to the British fauna.

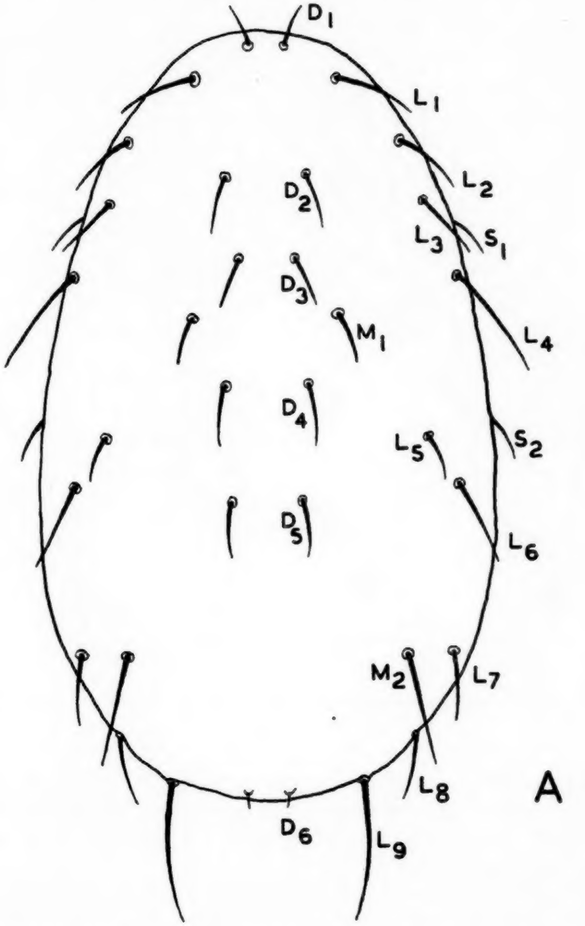

Fig. 1. *Typhlodromus umbraticus* sp. n. A, Female, dorsal.

1,A). Shield ranging from 305 to 348 μ in length, and 168 to 188 μ in width (20 specimens).

Average lengths of dorsal setae for 20 specimens: L1, 37 μ; L2, 30 μ; L3, 33 μ; L4, 50 μ; L5, 26 μ; L6, 47 μ; L7, 30 μ; L8, 26 μ; L9, 64 μ; M1, 20 μ; M2, 50 μ; D2, 26 μ; D3, 20 μ; D4, 23 μ; and D5, 23 μ; mean distances between setae L1-L2, 34 μ; L2-L3, 26 μ; L3-L4, 34 μ; L4-L5, 70 μ; D3-D3, 20 μ; D2-D3, 26 μ; D3-M1, 34 μ; and M1-D4, 34 μ. Thus, the anterior lateral setae are approximately equal in length to the distances between their bases, and the dorsal setae are only slightly less than the distances between their bases.

Setae S1 and S2 (scapular and lumbar setae) on the interscutal membrane.

Sternal shield bearing three pairs of simple setae, the third pair being on slight posterolateral projections of the shield (Fig. 2,A). Metasternalia conspicuous and each bearing a simple seta. Genital shield normal.

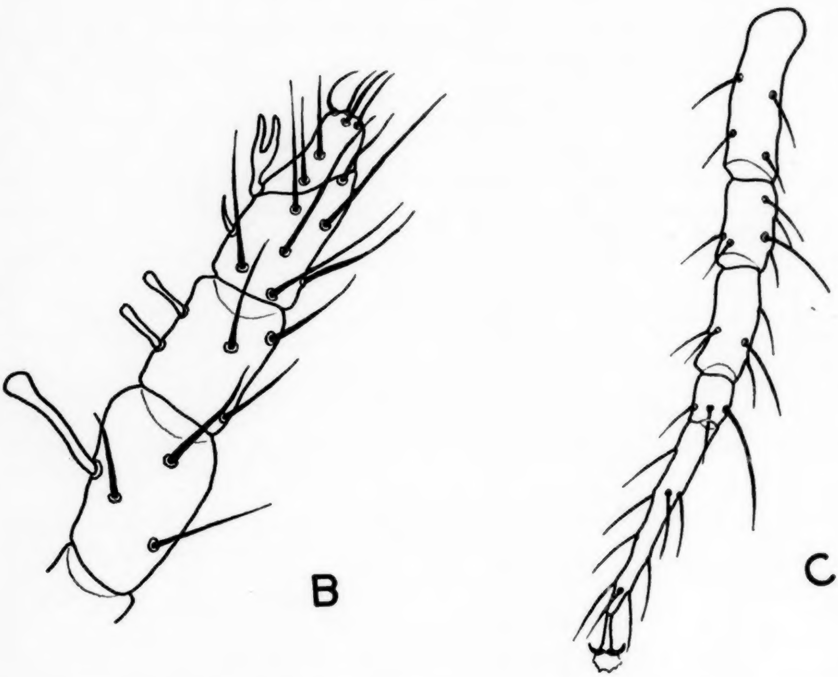

Fig. 1 (continued). *Typhlodromus umbraticus* sp. n. B. Female, maxillary palp. C. Female, leg IV.

Ventri-anal shield from 101 to 114 μ in length and 80 to 87 μ in width, shaped as in many other members of the genus, and bearing three pairs of setae in addition to para-anal and post-anal seta. A pair of pores present slightly posteromediad to third pair of setae.

Gnathosoma and maxillary palps normal, except that femur, genu, and tibia of the latter bear distinctly spatulate setae (Fig. 1,B). Fixed digit of chelicera 34 μ in length, bearing five teeth and a strong pilus dentilis (Fig. 2,B). Movable digit 26 μ in length, bearing two teeth. In a few specimens the second of these is very weak and barely discernible.

Genual, tibial, and basi-tarsal joints of leg IV bearing macrosetae 34 to 37 μ, 26 to 30 μ, and 40 to 77 μ in length, respectively (Fig. 1,C).

Male.–Chaetotaxy of dorsal shield similar to that of female except that setae S1 and S2 appear on its edge instead of on interscutal membrane. This is usual for mites of this and allied genera (Evans, 1954). Seta L9 varying from 43 to 45 μ in length, and seta M2 from 40 to 42 μ in length (10 specimens). Dorsal shield from 245 to 265 μ in length and 121 to 147 μ in width.

Ventri-anal shield (Fig. 2,D) from 104 to 107 μ in length and 124 to 137 μ in width, bearing six pairs of setae in addition to para-anal and post-anal setae.

Fixed digit of chelicera 20 to 23 μ in length, bearing seven teeth and a strong pilus dentilis (Fig. 2,C). Movable digit 16 μ in length, bearing one tooth and a lobed spermatophoral process.

Macroseta on basi-tarsal joint of leg IV 34 to 40 μ in length.

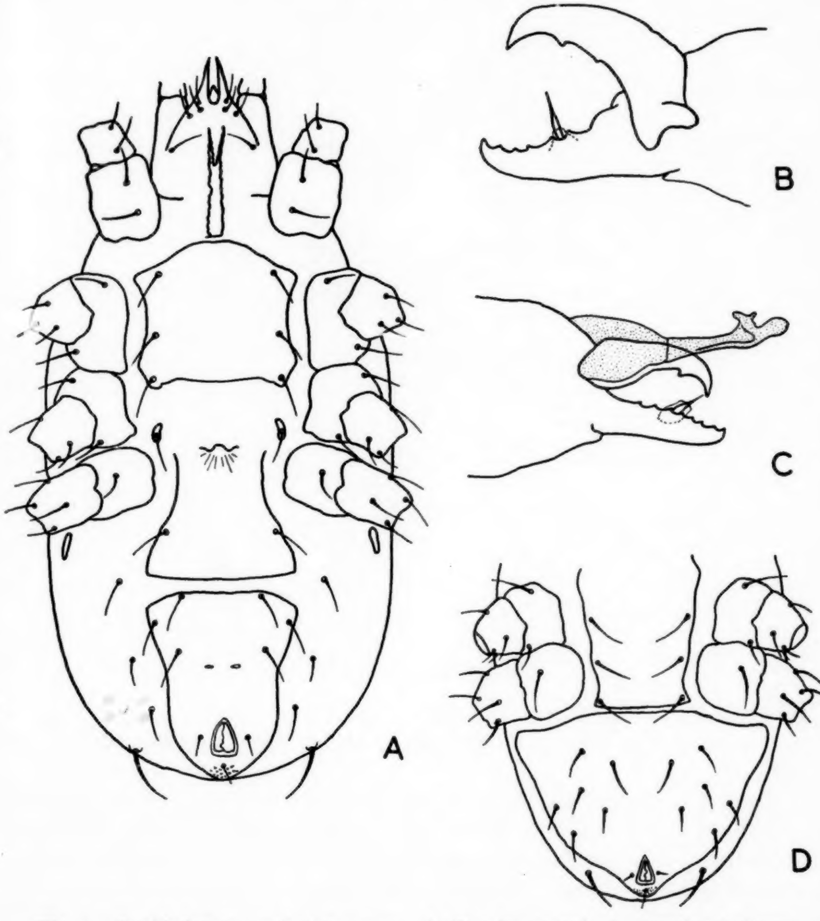

Fig. 2. *Typhlodromus umbraticus* sp. n. A, Female, ventral. B, Female, chelicera. C, Male, chelicera. D, Male, ventral.

Locality.–The type material, consisting of 56 females, was collected by the author from the leaves of *Rubus fruticosus* L. at Newgate Shaw, East Malling Research Station, Kent, during October, 1954.

The species is common in Kent and Essex and has been taken in large numbers both by the author and by Dr. Elsie Collyer of the East Malling Research Station. It has been collected from apple and other trees and shrubs, but undoubtedly prefers the low-growing herbs commonly found in shaded situations in woodlands and uncultivated orchards. A list of the plants from which the author has collected this species includes the following: *Rubus fruticosus* L., apple leaves and bark, *Ranunculus* sp., *Crataegus oxyacantha* L., *Quercus robur* L., *Corylus avellana* L., *Prunus spinosa* L., *Heracleum sphondylium* L., *Urtica dioica* L., *Convolvulus* sp., *Pteris aquilinum* (L.), *Fragaria vesca* L., and moss.

Adult females inhabiting the leaves of *R. fruticosus* have been observed feeding on the immature stages of *Eotetranychus carpini* (Oudemans) and on

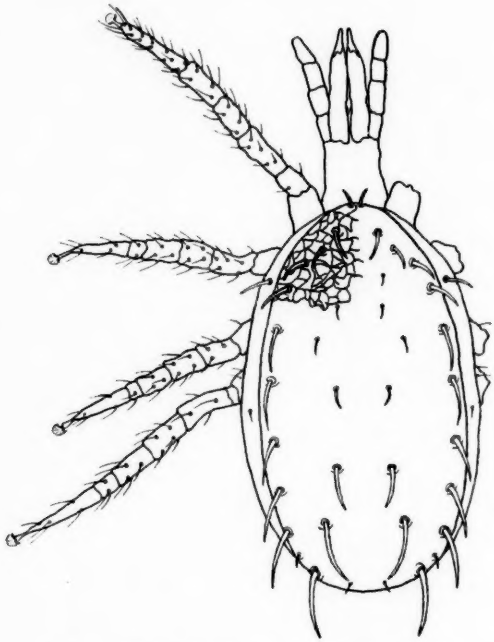

Fig. 3. *Seiulus simplex* sp. n. Female, dorsal.

newly moulted Collembola of the family Sminthuridae. They also feed on eriophyids.

The type material has been deposited in the British Museum (Natural History) and several paratypes will be placed in the Canadian National Collection.

On the basis of its chaetotaxy, this species is similar to *T. masseei* Nesbitt, *T. fallacis* (Garman), and *T. bellinus* Womersley. It has been compared with specimens of the former collected at Court Lodge, East Malling (one of the localities given by Nesbitt, 1951), and with specimens of *T. fallacis* sent to Dr. Collyer by Miss H. J. Herbert, Science Service Laboratory, Kentville, Nova Scotia. *T. umbraticus* can be separated from these and other species possessing nine lateral dorsal setae with seta M2 and L7 paired, and with three pairs of setae on the ventri-anal shield, by the following key, based on Nesbitt (*loc. cit.*).

A1. The six setae of the dorsal hexagonal area shorter than the distance between their bases....B
- B1. Anterior lateral setae L1 to L4 greater in length than the distances between their bases.......*T. masseei* Nesbitt
- B2. Anterior lateral setae L1 to L4 much shorter than the distances between their bases....C
  - C1. Setae M2 and L9 simple.......D
    - D1. Dorsum reticulate; ventri-anal shield triangular and as broad as long *T. reticulatus* Oudemans
    - D2. Dorsum only mildly imbricate; ventri-anal shield hexagonal and 1½ times as long as broad.......*T. cucumeris* Oudemans
  - C2. Setae M2 and L9 pectinate.......*T. asiaticus* Evans
- B3. Anterior lateral setae approximately equal in length to the distances between their bases.......C
  - C1. Seta L9 nearly twice as long as seta M2.......*T. bellinus* Womersley
  - C2. Seta L9 not more than 1.4 times as long as seta M2.......*T. umbraticus* sp. n.

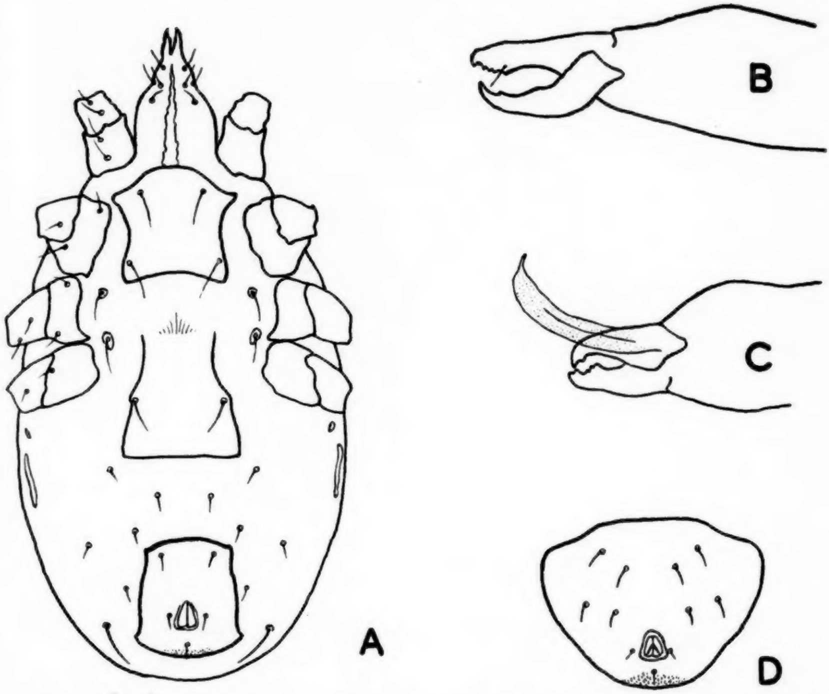

Fig. 4. *Seiulus simplex* sp. n. A, Female, ventral. B, Female, chelicera. C, Male, chelicera. D, Male, ventri-anal shield.

A2. The six setae of the dorsal hexagonal area equal to or somewhat longer than the distances between their bases; anterior lateral setae longer than the distances between their bases .... *T. fallacis* (Garman)

T. umbraticus further differs from *T. bellinus* in the dentition of the chelicerae, in the number of macrosetae on leg IV, and in the measurements of the dorsal shield.

Typhlodromus bakeri (Garman), 1948

Male.—Chaetotaxy of dorsal shield similar to that of female except that setae S1 and S2 appear on its edge instead of on the interscutal membrane. Dorsum rugose and from 241 to 281 μ in length, and 147 to 174 μ in width, for 10 specimens (Fig. 7,A).

Ventri-anal shield reticulated, from 90 to 111 μ in length and 124 to 140 μ in width, and bearing five pairs of setae in addition to para-anal and post-anal seta (Fig. 7,A).

Fixed digit of chelicera from 20 to 33 μ in length and bearing one tooth together with a strong pilus dentilis. Movable digit 16 μ in length, bearing one tooth together with a spermatophoral process (Fig. 7,B).

Legs short and stout, bearing a macroseta 23 μ in length on basi-tarsal joint of leg IV.

Locality.—This is the first British record of the species, although it is one of the most common in southeastern England. It is a bark-inhabiting species and rarely has been recorded from foliage.

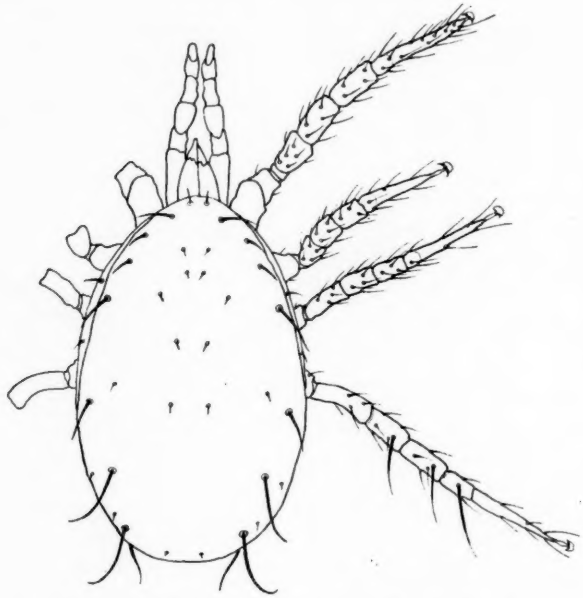

Fig. 5. *Amblyseius graminus* sp. n. Female, dorsal.

The males from which this description was made were reared from females collected from the bark of unsprayed apple trees at Ulcombe, Kent. Additional specimens numbering several hundreds have been collected in Kent and Essex from the bark of the following trees: *Ulmus* sp., *Pinus sylvestris* L., *Castanea sativa* Mill., *Sambucus niger* L., *Fagus sylvatica* L., *Crataegus oxyacantha* L., *Quercus robur* L., *Corylus avellana* L., *Sarothamnus scoparius* (L.), *Betula alba* L., *Fraxinus excelsior* L., and from *Pteris aquilinum* (L.), *Lonicera periclymenum* L., and *Caluna vulgaris* (L.).

The species has been recorded from Connecticut, U.S.A. (Garman, *loc. cit.*) Nova Scotia, Canada (Nesbitt, *loc. cit.*), Australia (Womersley, 1954), and now England. Also, the author has found it in a collection of mites from the bark of *Pinus contorta* Loud. and *P. strobus* L. from Vancouver, Canada. Apparently it has a wide distribution throughout the world.

Typhlodromus polonicus (Willmann), 1949, comb. nov. and _T. marinus_ (Willmann), 1952, comb. nov.

These species were originally placed in the genus *Lasioseius* Berlese, 1916 (Willmann, 1949 and 1952). Both are typical of the genus *Typhlodromus* and for that reason are included here by the present author. Dr. G. Owen Evans extracted *T. polonicus* by means of a Berlese funnel from turf collected in the gardens of the British Museum (Natural History) in South Kensington, London, on March 15, 1954. Both Dr. Evans and the author have collected *T. marinus* by similar means from seaweed and other debris collected at high-water mark on the Thames Estuary at Rochester and Elmstead Ferry, both in Kent, in July, 1955.

Seiulus simplex sp. n.

Female.—Dorsal shield deeply sculptured and bearing 19 pairs of setae arranged in a lateral row of eleven, a dorsal row of six, and a median row of

two pairs (Fig. 3). These setae are extremely thick and thorn-like but are without serrations. Lateral series from 16 μ (L2) to 61 μ (L11) in length. Seta M2 57 μ in length.

Dorsal shield from 314 to 348 μ in length and 168 to 194 μ in width (15 specimens).

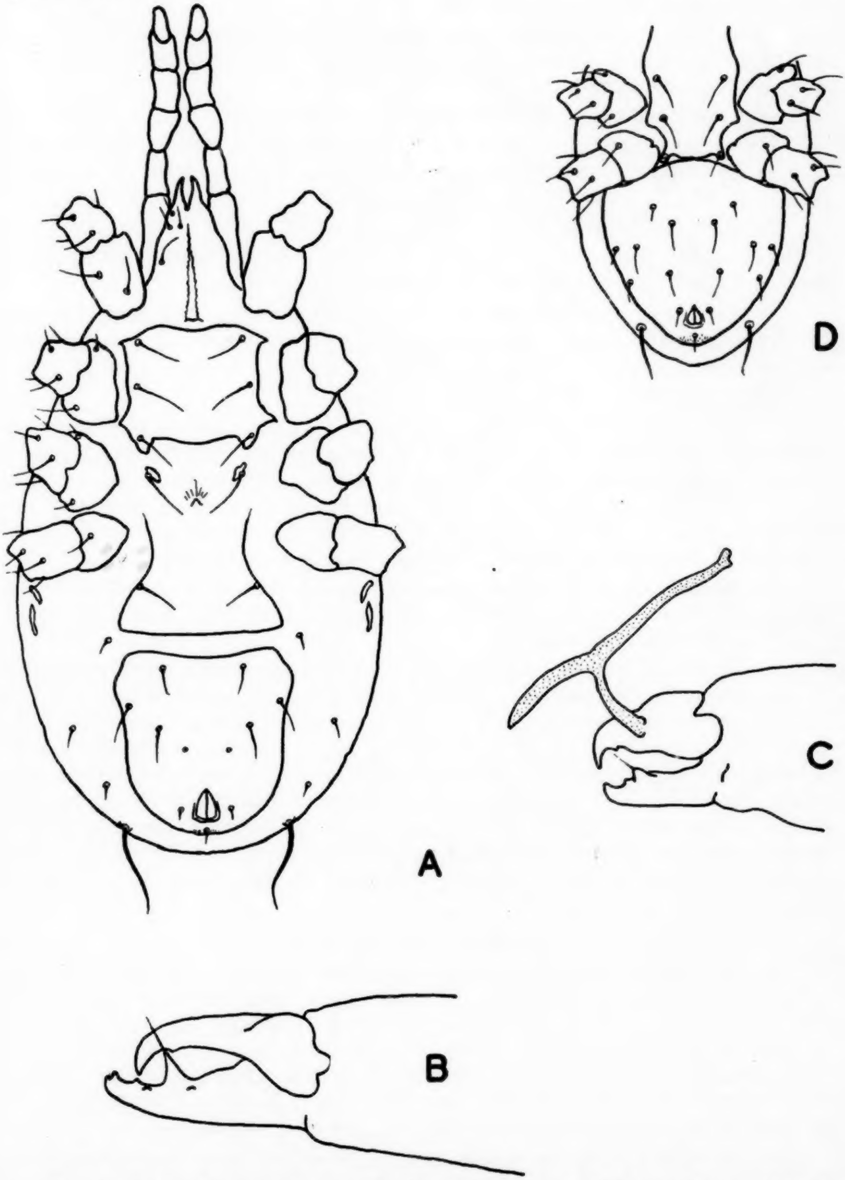

Fig. 6. *Amblyseius graminis* sp. n. A, Female, ventral. B, Female, chelicera. C, Male, chelicera. D, Male, ventral.

Sternal shield bearing two pairs of simple setae (Fig. 4,A). Third and fourth pairs of sternal setae situated individually on distinct platelets. Genital shield normal.

Ventri-anal shield almost square, from 67 to 80 μ in length, from 64 to 73 μ in width, and bearing only one pair of setae in addition to para-anal and post-anal setae. Ventri-anal shield without pores.

Gnathosoma and maxillary palps normal. Fixed digit of chelicera 23 μ in length and bearing four small teeth together with a fine pilus dentilis (Fig. 4,B). Movable digit 20 μ in length and bearing one tooth.

Legs short and stout and bearing no specialised setae.

Male.—Chaetotaxy of dorsal shield similar to that of female except that setae S1 and S2, borne on interscutal membrane of female, are on edge of the shield. Seta L11 and M2 34 and 30 μ in length respectively.

Dorsal shield 298 μ in length and 147 μ in width.

Ventri-anal shield 113 μ in length, 126 μ in width, and bearing four pairs of setae in addition to para-anal and post-anal setae (Fig. 4,D).

Fixed digit of chelicera bearing four teeth but in the specimen examined the pilus dentilis is absent. Movable digit bearing one tooth and a spur-shaped spermatophoral process. Fixed digit 16 μ in length and movable digit 13 μ.

The male is known from a single specimen.

Locality.—The holotype female was found by the author on pieces of bark collected in September, 1954, by Mr. J. B. Briggs of the East Malling Research Station, from *Fagus sylvatica* L. (beech) at Barming Heath, Kent. Later, additional specimens were collected from the same tree and from a neighbouring oak, *Quercus robur* L. During the winter of 1954-55 the species was found to be abundant on the bark of oak trees in Oaken Wood, East Malling, Kent.

The holotype and three paratypes (all female) have been deposited in the British Museum (Natural History) and specimens will be deposited in the Canadian National Collection.

A discussion of the genus *Seiulus* is contained in Nesbitt's (1951) revision of the subfamily Phytoseiinae. The type material of the genotype, *Seiulus hirsutigenus* Berlese, has been lost and the systematic status of the genus is still uncertain. *Seiulus simplex* sp. n. is close to *S. hirsutigenus* but from Berlese's drawings can be seen to differ from it in the form of the anterior lateral setae of the dorsal shield, in possessing a true ventri-anal shield, and in the location of the sternal setae. In the latter, the anterior lateral setae are serrated and slender, there is no true ventri-anal shield there being merely an anal plate bearing two para-anal and a post-anal setae, and the first three pairs of sternal setae are on the sternal shield.

Amblyseius graminis sp. n.

Female.—Dorsal shield smooth and appearing heavily sclerotized. Bearing 17 pairs of simple setae, arranged in a lateral row of nine, a median row of two, and a dorsal row of six pairs (Fig. 5). Setae L1, 23 to 40 μ; L2, 16 to 30 μ; L3, 20 to 33 μ; L4, 49 to 70 μ; L5, 10 to 16 μ; L6, 30 to 40 μ; L7, 10 to 16 μ; L8, 10 to 16 μ; L9, 70 to 100 μ; M1, 6 to 10 μ; M2, 50 to 65 μ; D1, 21 to 29 μ; D2, 12 to 14 μ; D3, 6 to 10 μ; D4, 6 to 10 μ; D5, 9 to 11 μ. Dorsal shield from 314 to 368 μ in length and from 194 to 255 μ in width (15 specimens).

Sternal shield bearing three pairs of setae, third pair being on small but stout posterolateral projections (Fig. 6,A). Metasternal plates conspicuous and each bearing a seta. Genital shield normal.

Ventri-anal shield from 97 to 130 μ in length and from 83 to 120 μ in width, bearing three pairs of setae in addition to para-anal and post-anal setae. A pair of small pores present posterior to third pair of setae.

Seta VL1 from 50 to 60 μ in length and thus approximately $\frac{3}{5}$ the length of seta L9.

Gnathosoma and maxillary palps normal. Fixed digit of chelicera from 30 to 33 μ in length, bearing two small teeth and a strong pilus dentilis (Fig. 6,B). Movable digit from 23 to 30 μ in length, bearing one small tooth.

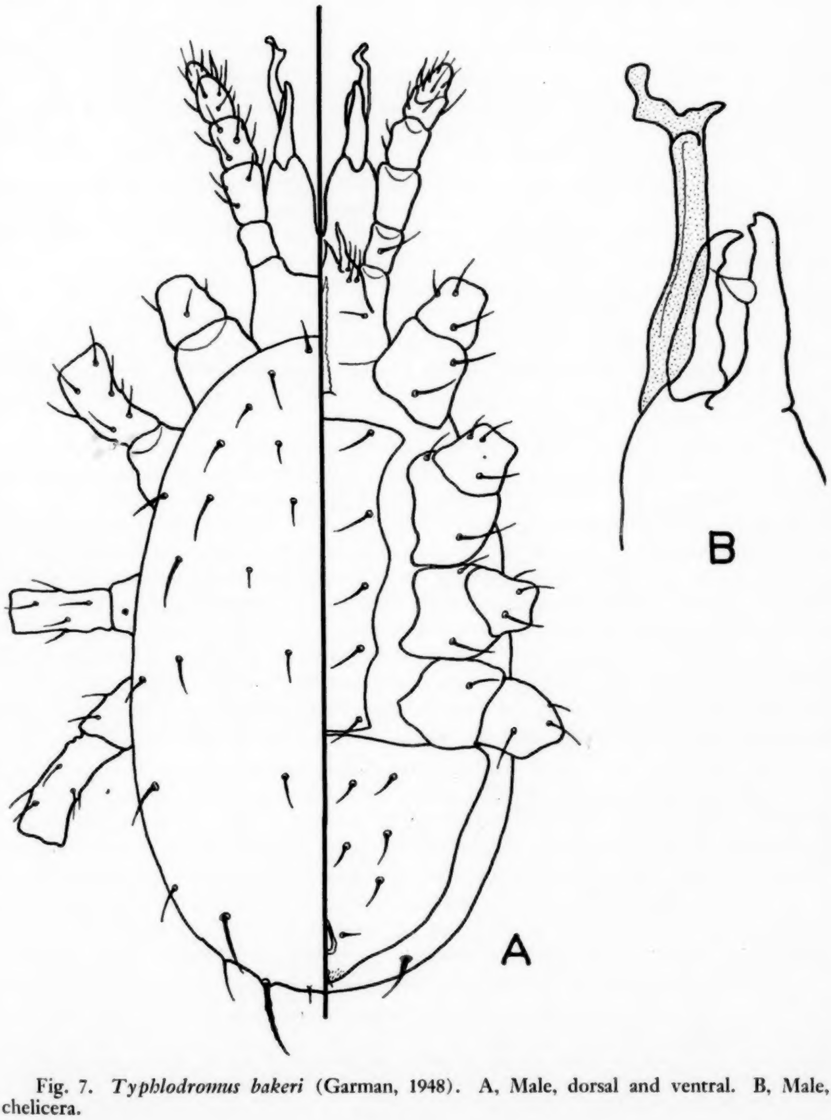

Fig. 7. *Typhlodromus bakeri* (Garman, 1948). A, Male, dorsal and ventral. B, Male, chelicera.

Legs long and slender and bearing macrosetae on genual, tibial, and basi-tarsal joints of leg IV measuring 47, 33 and 70 μ respectively.

Male.—Chaetotaxy of dorsal shield similar to that of female except that setae S1 and S2 appear here instead of on the interscutal membrane. Dorsal shield averaging 261 μ in length and 144 μ in width for 10 specimens.

Measurements of important setae on dorsal shield: L1, 26 μ; L4, 34 μ; L9, 50 μ; M2, 44 μ. Shield appearing smooth and heavily sclerotized.

Ventri-anal shield (Fig. 6,D) 107 μ in length and 107 μ in width and bearing six pairs of setae in addition to para-anal and post-anal setae arranged as in male of *Typhlodromus umbraticus* sp. n.

Seta VL1 26 μ in length.

Fixed digit of chelicera from 20 to 23 μ in length and bearing two teeth together with a strong pilus dentilis (Fig. 6,C). Movable digit from 16 to 20 μ in length and bearing one tooth together with a branched spermatophoral process.

Legs long and slender; three macrosetae on leg IV measuring 33 μ (genual), 20 μ (tibial), and 53 μ (basi-tarsal).

Locality.—This is the most common species of Phytoseiidae inhabiting grasses in Kent and Essex. It probably feeds on tetranychids and other small mites.

The type material was collected from grass at the edge of an orchard in East Malling, Kent. Other specimens have been collected from Boxley Hill, Ashford, Romney Marsh, and Hawkhurst in Kent, and from Penlan Hall near Fordham, and Maldon in Essex. The list of host plants includes *Convolvulus* sp. and *Rubus fruticosus* L.

The holotype and several paratypes have been deposited in the British Museum (Natural History) and specimens of both sexes will be deposited in the Canadian National Collection.

The genus *Amblyseius*, although closely related to *Typhlodromus*, may be separated from it by the relative lengths of certain dorsal and posteroventral setae. In *Amblyseius* L4, L1, L9, and M2 of the dorsal shield, and seta VL1 of the posteroventral setae, are considerably longer than the remainder of the dorsal and ventral setae.

Many of the species in the genus have been inadequately described and this has led to some confusion regarding the identity of certain species. The major work on the genus was that of Berlese (1914).

A. graminis is similar to *T. umbraticus* and other members of the genus *Typhlodromus* in the location of the setae on the dorsal shield, but may be distinguished from them on the above basis. The relative lengths of the setae make the species distinct among the members of the genus *Amblyseius*.

Acknowledgments

The author wishes to thank Dr. G. Owen Evans of the British Museum (Natural History) for his help with both the form and the content of this paper and for kind permission to include his capture of *Typhlodromus polonicus* in England. The work was conducted at the East Malling Research Station, Kent, under the direction of Dr. A. M. Massee, whom the author also wishes to thank. During part of the time the author was engaged in the study of predacious mites in England he was in receipt of a Special Scholarship for Overseas Study granted by the National Research Council of Canada; this is gratefully acknowledged.

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(Received November 22, 1955)

Selection of Populations of the Granary Weevil *Sitophilus granarius* L. more Resistant to Methyl Bromide Fumigation[1]

By H. A. U. Monro[2] and E. Upitis[3]
Science Service Laboratory, London, Ontario.

Today methyl bromide is being used throughout the world to control insect pests. Intrinsically it is not among the most toxic of insect fumigants, but it has a combination of properties which gives it an unique position among gaseous insecticides. Of particular importance are its powers of penetration and its non-inflammability under normal fumigating conditions. Methyl bromide is important also as the leading fumigant in a group, the halogenated hydrocarbons, which includes other widely used fumigants such as ethylene dibromide, ethylene dichloride, and ethylene chlorobromide.

Insects attacking stored products, especially, are being fumigated regularly with methyl bromide and related compounds. This group of insects is cosmopolitan, and, furthermore, populations of many species are being moved continually from one country to another in plant products through the medium of carriers such as ships. It may be assumed, therefore, that many populations of these insects are subjected to the selective action of such fumigants. In this note it is not necessary to enlarge on this problem as it has already been discussed at some length by one of us (Monro, 1950).

In January 1953 work was started at this laboratory to determine if significantly different degrees of tolerance to methyl bromide could be demonstrated in insect populations as the result of continued selection. The insect species chosen for this programme were the confused flour beetle, *Tribolium confusum* Duv., the granary weevil, *Sitophilus granarius* L., and the cadelle, *Tenebroides mauritanicus* (L.). This note reports the isolation of two populations of *S.*

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[3]Technical Officer.

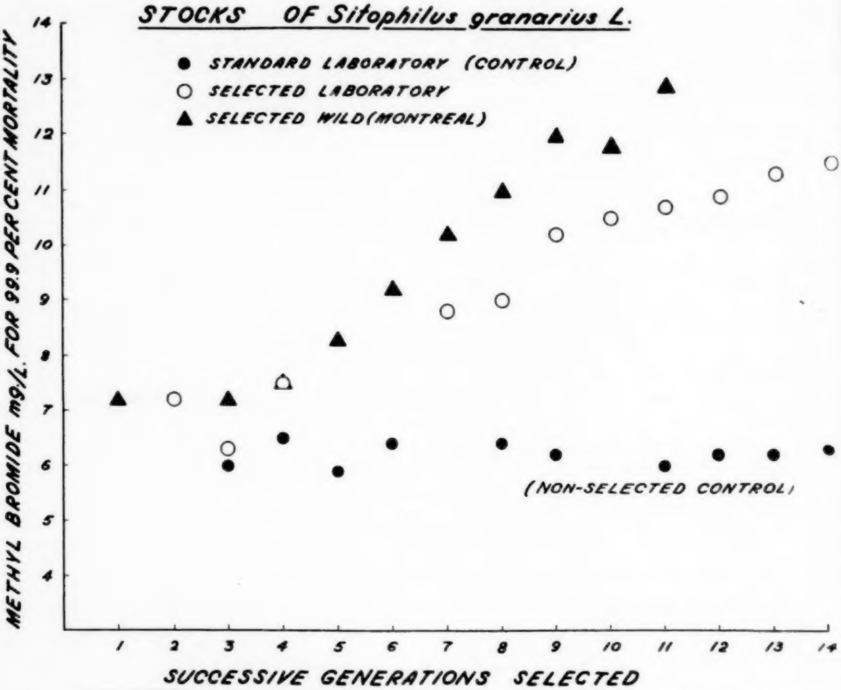

Fig. 1. History of selection of increased tolerance to methyl bromide fumigation of two stocks of adult *S. granarius*. Exposure to the fumigant for 5 hours at 25°C and 70 per cent relative humidity.

granarius in which the adults are significantly more resistant to the fumigant than the adult descendants of the original non-selected stocks.

At present three stocks of granary weevils are being subjected to the selection, as follows:—

(1) *Standard Laboratory Stock*: This has been reared continuously in the Montreal and London laboratories since 1936. It was obtained in that year from Dr. H. E. Gray of the Entomology Division, Ottawa, who states that the population originated from collections made in the region of Brantford, Ontario.

(2) *Montreal "Wild" Stock*: This stock was started from collections made in 1950 in the holds of cargo ships entering the port of Montreal from overseas.

(3) *London "Wild" Stock*: This originated in 1951 from collections made at various elevators in Western Ontario by inspectors of the Board of Grain Commissioners.

The fumigation research equipment at this laboratory, to be described elsewhere, has been designed to provide a uniform environment so that conditions for a given experiment can be reproduced from month to month or year to year. The results obtained with the fumigation of a standard laboratory stock of *S. granarius* over a two year period (Fig. 1, non-selected control) indicate that this uniformity has been achieved.

In this work the insects have been exposed in every phase of the programme

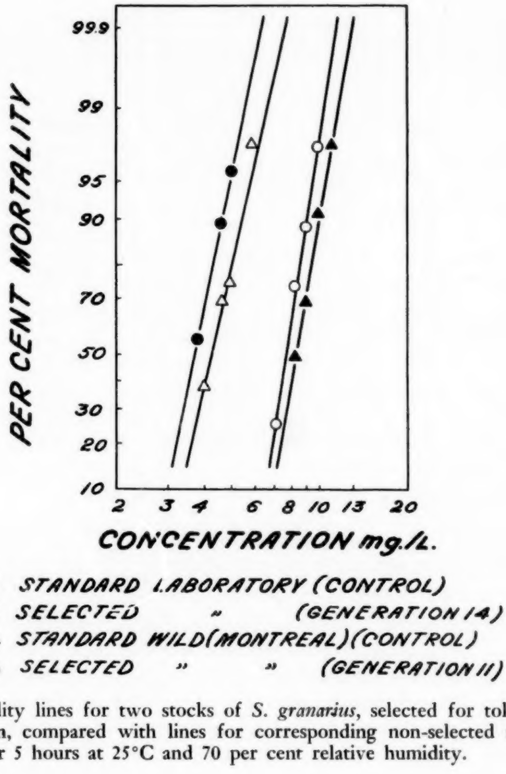

Fig. 2. Mortality lines for two stocks of *S. granarius*, selected for tolerance to methyl bromide fumigation, compared with lines for corresponding non-selected stocks. Exposure to the fumigant for 5 hours at 25°C and 70 per cent relative humidity.

to a temperature of 25°C and a relative humidity of 70 per cent. In the treatments, adults 7-14 days old have been exposed to the fumigant for 5 hours at atmospheric pressure.

A programme of selection with beetles attacking stored products is necessarily slow. Thus, since the beginning of the work with *S. granarius* only 14 successive generations have been treated.

In order to maintain the population at a level adequate for continuing the programme, selection of adults for breeding the next generation has been made from the survivors of treatments yielding mortalities of 75 per cent or more. Recently King (1954 and 1955) working with populations of *Drosophila melanogaster* Meigen has shown that, with one stock of this insect, increased resistance has developed more rapidly by selection of survivors at LD_{50} and upwards, rather than at LD_{90} or LD_{95}. Accordingly, early in 1955, we began another programme of selection of our stocks at the lower levels of mortality. So far this extension of the work has yielded no results of interest.

At each generation the weevils have been exposed to at least three different concentrations, chosen not only to ensure the desired selection, but also to supply data for the plotting of a mortality curve. The mortality data has been plotted on logarithmic probability paper and the LD_{50} and $LD_{99.9}$ obtained according to the method of Litchfield and Wilcoxon (1949).

TABLE I

Tolerance to Methyl Bromide Fumigation of two selected Populations of *S. Granarius* L. compared with standard non-selected Populations

Comparison of populations	Symbol	Concentration methyl bromide[1]		Test for parallelism of regression lines	Potency Ratio (with 95 per cent confidence limits)
		LD_{50}	Range of 95 per cent confidence intervals		
Selected Montreal Wild at 11th selection	MW_{11}	8.2	8.0–8.4	Deviation from parallelism not significant	1.9 (1.7–2.1)
—VERSUS—					
Standard (non-selected) Montreal Wild	MWS	4.2	4.1–4.4		
Selected Laboratory at 14th selection	R_{14}	7.7	7.5–7.9	Deviation from parallelism not significant	2.1 (1.9–2.3)
—VERSUS—					
Standard (non-selected) laboratory stock	RS	3.7	3.6–3.8		

[1]Concentration of methyl bromide, expressed in milligrams per litre, for 5 hours at 25°C.

So far, two of the populations, the Montreal Wild and the Standard Laboratory, have demonstrated a significant increase in resistance. The history of the programme of selection with these is set out in Fig. 1. In this figure the $LD_{99.9}$ for the weevils has been chosen to record the progress of the work, as this level of mortality gives a better picture of the practical implications of the study. Mortality lines for the two selected populations and their corresponding non-selected controls, obtained from the results of the most recent fumigation tests, are shown in Fig. 2. In Table 1 are set out the potency ratios for the selected and non-selected stocks at this stage of the investigation. It will be seen that the LD_{50} for selected Montreal Wild and Laboratory populations is approximately twice that of the corresponding non-selected controls.

To our knowledge, at the time of writing, this is the first demonstration of the emergence of a population of an insect more resistant to methyl bromide than the stock from which it has been derived. The work of selection will be continued, and an investigation will be started to determine the pertinent biological factors influencing the appearance of the more resistant lines.

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Fifth Annual Meeting of the Entomological Society of Canada

The Entomological Society of Canada held its fifth annual meeting jointly with the sixteenth annual meeting of the Acadian Entomological Society at the Lord Beaverbrook Hotel, Fredericton, N.B., on October 18 to 20. A total of 157 members and friends attended, including 14 from the United States, three from outside North America, and 31 wives and husbands. In the unavoidable absence of Rev. O. Fournier, President, Entomological Society of Canada, R. Glen, Vice-President, presided. Dr. H. S. Wright, Mayor of Fredericton, welcomed the two societies to the city, and F. M. Cannon, President, Acadian Entomological Society, welcomed the Entomological Society of Canada.

Invitation papers were presented during two sessions by four prominent zoologists, and a session was devoted to a symposium on insect pollinators of legume seed crops. Papers of which the titles had been submitted were presented at one session of three sctions.

At a banquet on the evening of October 19, Dr. R. Glen was Chairman and Premier H. J. and Mrs. Fleming, Mayor H. S. and Mrs. Wright, and Mrs. R. P. Gorham were honoured guests. Premier Flemming welcomed all on behalf of the Province of New Brunswick and spoke briefly on the importance of the entomological work being conducted in the Province. Senator Muriel Fergusson, the guest speaker, was introduced by F. M. Cannon and gave an interesting account of NATO and of her visit to Canadian defence installations in Europe as one of a parliamentary group. A cocktail hour, provided by courtesy of Imperial Oil Ltd., preceded the banquet. A total of 183 members and friends attended.

An open house and tea in the Forest Biology Laboratory on the afternoon of October 17 and a social evening at the Lord Beaverbrook Hotel on October 18 were also much enjoyed.

On October 18 the ladies were entertained at a luncheon at Colewell's Inn and visits to the Anglican cathedral and the general shopping area of the city, and on October 19 a tour of the University of New Brunswick campus and an exhibit of paintings from the Beaverbrook collection at the University library.

At the close of the opening session on October 18, as part of the annual business meeting, J. A. Downes summarized the progress in planning for holding the Tenth International Congress of Entomology at Montreal on August 17 to 25, 1956. In general, the plans were well advanced, though some schedules had not been met. The second circular, giving general information and many details of the program, was expected to be released within a few weeks. There was considerable discussion, especially on the need for and the possibility of raising considerably more money than was so far promised; it was pointed out that, as the Society was sponsor of the Congress, the Society was responsible for financing the meetings.

At the main business session, on October 20, B. M. McGugan supplied copies of A. B. Baird's audited report as Treasurer for 1954 and gave an interim report for January 1 to October 4, 1955. The latter showed an estimated deficit of $278.24; however, the Society had loaned $1,000 to the Congress Committee and about $600 had been received on previous years' operations.

On motion of A. P. Arnason and C. W. Farstad, it was agreed, that, as entomologists, had greater interest in the success of the Congress than any other group in Canada, the Society should allocate a minimum of $1,000 and, and the discretion of the Board, a maximum of $2,000 to the Congress.

The report of the Editor, W. R. Thompson, as summarized by the Secretary, indicated that the first supplement to *The Canadian Entomologist* had appeared

in April, 1955, and that two manuscripts were on hand for publication in the series.

A. V. Mitchener, Chairman, reported that the Committee on Common Names of Insects now consisted of chairmen of the committees for the various regional societies and two others, one of which was a systematist; H .T. Stultz had been appointed Secretary. During the year, eight suggestions for common names had been considered and six had been approved and forwarded to the Entomological Society of America.

M. E. Neary, L. G. Putnam, and H. A. Richmond were named as the Nominations Committee for the election by mail ballot in 1956 of officers for 1956-57. A. W. Fowler and R. W. Martin were re-elected as auditors for the year ending December 31, 1955.

After the Secretary read the minutes of a meeting of the Board on June 20 concerning the advisability of incorporating the Society, on motion of A. A. Beaulieu and W. N. Keenan it was agreed, almost unanimously, that the Society proceed with incorporation. B. M. McGugan outlined the basis under which an incorporated society would work and stated that if the revised constitution (by-laws) were approved in principle at the meeting then incorporation might become effective early in January. The draft of the revised constitution was submitted by J. M. Cameron and, with amendation, was approved in principle.

It was agreed that the annual meeting in 1956 be limited to a business session at the time of the Tenth International Congress of Entomology. A tentative invitation was received from the Entomological Society of Alberta to hold the annual meeting of the Society in Alberta in 1957.

R. H. Wigmore, *Secretary.*

Book Notice

The Eucalyptus Snout-Beetle, *Gonipterus scutellatus* Gyll, A Study of its Ecology and Control by Biological Means, by F. G. C. Tooke, M.Sc. (Cornell), Ph.D. (S. Afr.), Union of South Africa, Department of Agriculture, Entomology Memoirs, Vol. 3, 1955. 184 pp., 161 figs.

This is an important contribution which merits careful study by all those interested in the biological control of insect and plant pests. As has been noted, one of the major weaknesses with respect to operations in biological control, whether they are unsuccessful, inconclusive or successful, is the absence of detailed factual reports containing not only a complete account of the work undertaken but also an accurate evaluation of the results obtained. For example, we have some fine studies of the work of the parasites of the European corn borer giving very full details with respect to parasite establishment and percentage of parasitism; but though they contain much interesting information it is impossible to gather from them whether any economic effect has been obtained by the introduction of parasites. It is of course very difficult to demonstrate an economic effect unless the parasite finally produces a widespread and catastrophic reduction of the host population. Nevertheless, unless the work necessary to this end is carried out the value of the introduction must remain permanently in doubt.

Furthermore we lack definite and detailed information not only in regard to such cases but even in regard to those where an economic effect has been quite definitely obtained.

We must therefore be very grateful to Dr. Tooke for his very full and careful record of the work on the biological control of the Eucalyptus Snout-

beetle in South Africa. It is impossible to bring out in this short notice all the interesting points mentioned in his paper. We can refer only to some of the highlights. The genus Eucalyptus, as is well known is almost exclusively confined to Australia and Tasmania. About 176 species were introduced into South Africa and are now widely planted throughout the Union. Further introductions were prohibited in 1903 in recognition of the conspicuous freedom of Eucalyptus from serious pests in South Africa, while they were known to be afflicted with many insects in Australia. The Eucalyptus Snout-beetle, an Australian weevil, was first discovered in Cape Colony in November 1916 and was probably introduced into South Africa in shipments of apples from Australia some years prior to this date. By 1924 it had spread throughout practically the whole Eucalyptus growing areas in the Union and was attacking no less than 65 species of eucalyptus to a varying degree. By 1925 it had become such a menace to the Eucalyptus growing industry that immediate steps had to be taken to combat it.

In 1926 Dr. Tooke was sent to Australia to search for parasites of Gonipterus. He found three egg parasites and one larval parasite. Only one parasite, the mymarid *Anaphoidea nitens*, appears to have been identified and only this species was successfully introduced into South Africa. From 1928 to 1931 it was reared in large numbers in the laboratory and distributed throughout the four provinces of the Union. By 1927 it was known to have become established. By 1928 the parasitism in certain areas had risen to 30% and by 1930 had attained over 90% in many districts. By that time the Eucalyptus plantations in many cases showed a very definite improvement. In the 1932-33 season the parasite declined in effectiveness owing apparently to a severe drought. However it soon recovered and by May 1950 almost 70% of the plantations containing susceptible species of Eucalyptus were reported in good condition.

Several important conclusions emerge from this experiment. The first is that a decisive biological control of pests is possible in continental as a distinct from island areas. The suggestion that outstanding successes in biological control are generally possible only in island areas long ago made by A. D. Imms has recently been revived by T. H. C. Taylor. When success in continental areas is obtained this is alleged to be due to the ecological isolation of parts of these areas so that they are similar to islands. The authors who hold this view have never been able to produce any well founded reason to explain the principle they defend. At all events it can hardly be claimed in this case that the vast area over which *Anaphoidea nitens* has controlled the Eucalyptus Snout-beetle is in any sense an island area.

A second important point is that when the mymarid parasite was discovered in Australia practically nothing was known about it and although a fairly high parasitism was observed in one place in Australia the minute size and apparent fragility of the mymarid might well have caused Tooke to doubt its usefulness as an effective controlling agent. Some workers claim the effective control can usually be obtained only by the work of a sequence of parasites attacking the various developmental stages of the host insect. Here however we have the control of an insect by a single species of egg parasite. We are therefore justified in concluding that though outstanding successes in biological control work are rather infrequent they may be obtained even under conditions that seem quite unfavourable. The establishment of *Anaphoidea nitens* against *Gonipterus scutellatus*, says Tooke, saved the country several million pounds. It must be admitted that so far as one can tell the successful experiments in

biological control are due rather to good luck than to careful planning. Nevertheless it is amply clear that the successes obtained justify the expenditure involved and we may hope that when we understand the natural control of insect and plant pests more fully we can improve on our present methods.

W. R. Thompson.

Kenneth Bowman

The death of Kenneth Bowman at Edmonton on September 25, 1955 deprived Alberta of one of its most energetic collectors of Lepidoptera. Born at Durham, England in 1875 he early showed signs of developing into a keen student of natural history in all of its phases but his particular interest always centred around building comprehensive collections of the Lepidoptera of the districts in which he lived. Thus, when he came to Blackfalds in Alberta in 1904 and moved on to Edmonton in 1905, he quickly adapted his knowledge of the Macrolepidoptera of England to local conditions. His profession, as chartered accountant, took him frequently into three mountain passes which gave him an opportunity to collect extensively both on the plains and in the mountains of Alberta. By 1919 he had published a list of over 900 Macrolepidoptera taken in this province.

He now turned his attention increasingly to collecting the almost completely neglected Microlepidoptera of this part of Canada. He was blessed with the ability and the persistence to prepare well-nigh perfect specimens of these moths, many of which are exasperatingly minute and delicate.

Though he was fortunate, in his early years of collecting in this group, in obtaining taxonomic assistance in certain families from Dr. J. H. MacDunnough in Ottawa, he was seriously handicapped in later years by being unable to find any specialists on this continent who were willing or able to classify the bulk of his steadily increasing Microlepidoptera. He possessed an unusually well-developed "eye for species" which enabled him to build up many series of what were undoubtedly representatives of true species.

By 1951, however, he had so succeeded in his quest for determiners that he was in a position to publish a completely revised list containing over 1,800 names of the Lepidoptera of Alberta, of which the magnificent total of 653 referred to Microlepidoptera. Despite the advance he thus made towards a more complete knowledge of the Microlepidoptera of Alberta his collection contained somewhat over 100 species which, at the time of his death, no one had attempted to name. A reason, given by one specialist, is that many of these are undoubtedly "new to science".

Most appropriately, his entire collection has now been acquired by the University of Alberta where, with the equally valuable collection of Coleoptera made by the late Mr. F. S. Carr, it will take its place as a permanent memorial to the industry of two of Alberta's pioneer amateur Entomologists.

This, in part, is the lasting contribution made by Kenneth Bowman to a knowledge of the Lepidoptera of Canada. He recognized as "new" many of the Macrolepidoptera which he collected. Though he described a few of these himself, his more normal procedure was to give specialists the privilege of so doing.

Members of the recently established Entomological Society of Alberta, of which he was a charter member, mourn with Mrs. Bowman and her daughter the passing of a loved associate and friend but are grateful for the permanent benefit they have gained from his life-long devotion to his valuable hobby.

E. H. Strickland.

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